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POLLUTION OF LAKE MICHIGAN AND ITS TRIBUTARY BASIN. PROCEEDINGS OF CONFERENCE, SESSION (3RD) HELD AT CHICAGO, ILLINOIS, ON SEPTEMBER 28-OCTOBER 2, 1970. VOLUME 2

Federal Water Quality Administration
Washington, D.C.

2 October 1970

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PROCEEDINGS

MICHIGAN
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA

THIRD SESSION
RECONVENED IN
WORKSHOP SESSIONS

September 28, 29, 30,
October 1, 2, 1970.
Chicago, Illinois

Vol. 2,

CONFERENCE

Pollution of Lake Michigan and Its Tributary Basin

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U.S. DEPARTMENT OF THE INTERIOR . . . FEDERAL WATER QUALITY ADMINISTRATION

WORKSHOP SESSION FOR THE THIRD SESSION OF THE CONFERENCE IN THE MATTER OF POLLUTION OF LAKE MICHIGAN AND ITS TRIBUTARY BASIN IN THE STATES OF WISCONSIN, ILLINOIS, INDIANA, AND MICHIGAN --- VOLUME II

Louis XVI Room
Sherman House
Chicago, Illinois
September 29, 1970

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Workshop Session for the Third Session of the Conference in the Matter of Pollution of Lake Michigan and Its Tributary Basin, in the States of Wisconsin, Illinois, Indiana, and Michigan, held in the Louis XVI Room of the Sherman House, Chicago, Illinois, on Tuesday, September 29, 1970, at 9:00 a.m.

- - -

PRESIDING:

MURRAY STEIN, Assistant Commissioner
for Enforcement and Standards Compliance,
Federal Water Quality Administration,
U.S. Department of the Interior,
Washington, D.C.

- - -

CONFEREES:

BLUCHER A. POOLE, Technical Secretary,
Stream Pollution Control Board, Indiana
State Board of Health, Indianapolis,
Indiana.

PERRY E. MILLER, Assistant Director, Stream
Pollution Control Board, Indiana State Board
of Health, Indianapolis, Indiana.

RALPH W. PURDY, Executive Secretary, Michigan
Water Resources Commission, Lansing, Michigan.

CONFEREES (Continued):

FRANCIS T. MAYO, Regional Director, Federal Water Quality Administration, U.S. Department of Interior, Chicago, Illinois.

ALTERNATE CONFEREES:

DOUGLAS B. MORTON, Environmental Control Engineer, Illinois Environmental Protection Agency, Springfield, Illinois.

DAVID P. CURRIE, Chairman, Illinois Pollution Control Board, Chicago, Illinois.

JACOB D. DUMELLE, Member, Illinois Pollution Control Board, Chicago, Illinois.

CARLOS FETTEROLF, Supervisor, Water Quality Standards Appraisal, Michigan Water Resources Commission, Lansing, Michigan.

DONALD J. MACKIE, Assistant Secretary, Division of Environmental Protection, Wisconsin Department of Natural Resources, Madison, Wisconsin.

ROBERT P. HARTLEY, Director, Office of Enforcement and Cooperative Programs, Federal Water Quality Administration, U.S. Department of Interior, Chicago, Illinois.

PARTICIPANTS:

A. F. Aschoff, Head, Environmental Division, Sargent and Lundy Engineers, Chicago, Illinois.

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Byron O. Lee, Jr., Assistant to the President, Commonwealth Edison Company, Chicago, Illinois.

Wesley O. Pipes, Professor of Civil Engineering and Professor of Biological Sciences, Northwestern University, Evanston, Illinois.

William McNamara, Vice President, Madison Gas and Electric Company, P. O. Box 1231, Madison, Wisconsin 53701.

Donald W. Pritchard, Professor, The Johns Hopkins University, Baltimore, Maryland 21218.

Paul Keshishian, Director, Power Production, Wisconsin Power and Light Company, Madison, Wisconsin.

G. Fred Lee, Professor of Water Chemistry, University of Wisconsin, Madison, Wisconsin.

Andrew Robertson, Associate Professor of Zoology, University of Oklahoma, Norman, Oklahoma.

PARTICIPANTS, Continued:

Edward C. Raney, Professor of Zoology, Cornell University, Ithaca, New York.

- - -

Murray Stein

PROCEEDINGS

- - -

MR. STEIN: Let's reconvene, and we will continue with the presentation of the power industry. I thought of something this morning, and I guess this will just take a few minutes or less than that. But while the representatives of the power industry are here, I think -- at least I should make something clear to them because, as I see the discussions developing today, we are just dealing with a small part of what is popularly called "the thermal pollution problem," i.e., the return of heated water to a watercourse.

But I would like to suggest to you people that, in looking at the problem, we see this in a much clearer way. There are several aspects to the problem: 1) If you take water in from a watercourse in vast amounts, the very fact of taking that water in and having other water take its place may change the ecological characteristics of that body of water that you are dealing with when you use that as your intake water source. This has to be remedied. 2) We have the problem, in determining the fate of the minute organisms that are taken in with the water -- small fishes, snails, plankton, zooplankton, phytoplankton -- whether the heat that they are subjected to going through the operation affects them then or whether there is a delayed shock and they may be affected later, or whether just the mechanical bruising they get going through the system may affect them. Now, if this happens, what you may get is that these organisms don't live out their normal life cycle and you are dropping trillions of little carcasses in your outfall through your outfall line, and you may get a fairly rapid decay. 3) The third point, of course, is the one we have been discussing here: the effect of heat on the receiving water. 4) And the fourth is the reverse of the first. If you put vast amounts of water back into a watercourse at a particular point, even though you haven't changed that water at all, on that assumption, just putting that in physically you may, if that changed the ecological characteristics of that receiving body of water, unless the water you are putting in is exactly like the receiving body, if it doesn't have the plankton in it, if it somehow changed in the system when you are putting that in, and you are putting vast amounts in, the ecology of the receiving body of water may very well be different.

Now, I think with the representatives of the industry here, as I see it, and I think I am speaking for the Federal organization at any rate, we are going to have to consider all these aspects of the problem in the future.

Mr. Petersen, would you proceed?

MR. PETERSEN: Thank you, Mr. Chairman.

The presentation of Consumers Power Company is continuing this morning. Representatives of Sargent and Lundy Engineers will speak. First will be Mr. A. F. Aschoff, Head of the Environmental Division for Sargent and Lundy, who will speak on "Thermal Discharges in Proper Perspective." He will be followed by Mr. R. W. Patterson, partner and Manger of the Mechanical Department, who will speak as to "Preliminary Comments on the U. S. Department of the Interior Reports on Lake Michigan Issued in September 1970."

Mr. Aschoff.

STATEMENT OF A. F. ASCHOFF, HEAD, ENVIRONMENTAL DIVISION, SARGENT AND LUNDY ENGINEERS, CHICAGO, ILLINOIS

MR. ASCHOFF: Mr. Stein, conferees, ladies and gentlemen. My name is A. F. Aschoff, and I am with the firm of Sargent and Lundy Engineers in Chicago.

I appreciate this opportunity of presenting additional information on the thermal problem.

This statement was prepared to help further the understanding of powerplant thermal discharges, especially as related to the physical laws of nature and natural behavior of waters.

Through this discussion, it is hoped that powerplant thermal discharges can be considered in their proper perspective in the broad scope of natural phenomena which are occurring continuously in the universe.

A discussion regarding thermal discharges necessitates a general understanding of the characteristics and behavior of natural bodies of water. This should include an appreciation of the world's supply of water and its continuing cycle, change in phase, and change in location. Natural variations occur in all natural bodies of water and are the result of many causes. One of these is the heat exchange between the earth and outer space.

With knowledge of the natural behavior of natural bodies of water, unnatural or manmade influences such as the addition of heat may then be superimposed and their magnitude compared to the natural background phenomena.

Physical characteristics of water such as density, viscosity and vapor pressure, as well as heat transfer, change with temperature. Understanding of these relationships is essential.

The ensuing discussion considers both the general aspects of thermal discharge and behavior of warmed water and the relationship of these factors to natural waters. Lake Michigan is considered particularly.

II. Natural Behavior of All Natural Bodies of Surface Water

The Water Cycle

In a broad sense water is never lost. The world supply of water circles endlessly from sky to land to ocean, and then back to sky again. Water rises from the ocean and is carried across the land, partly as invisible vapor and partly as tiny condensed droplets. Some of this moisture in air falls to earth as rain, sleet or hail. There a small amount quickly returns to the ocean as runoff, some goes underground to feed plant roots, or seeps back to the ocean. Most of the water on the earth's surface returns to the atmosphere by evaporation from land, water surfaces and plants. Within this mechanism, Figure 1, (See P. 637), the amount of water remains essentially constant. But the way water is distributed in the ocean, in the atmosphere, on and under land, varies from hour-to-hour, day-to-day, and month-to-month.

Variations in Surface Water Temperatures

A. F. Aschoff

Temperatures of natural bodies of water are also naturally dynamic. They change as the water flows from one location to the other, from hour-to-hour, between day and night, from month-to-month, and year-to-year.

For example, the temperature of the Mississippi River increases by 5 degrees Fahrenheit, from 75 degrees Fahrenheit to 80 degrees Fahrenheit, in its travel from south of Moline, Illinois, to north of Memphis, Tennessee. Estimating this distance as 400 miles would indicate that natural influences tend to increase the water temperature of a river by 1 degree Fahrenheit for each 80 miles it travels southward.

Surface water temperatures vary from day to night. A 24-hour change is called a diurnal variation. It should be noted that the actual magnitude of the diurnal change also varies from day-to-day in a given month. For example, in the month of June 1954, the diurnal change of the Vermilion River in Illinois ranged from 2 degrees Fahrenheit to 12 degrees Fahrenheit.

Natural water temperatures vary month by month and the monthly temperatures may also differ from year to year. Data from the Vermilion River shows an average 43 degree Fahrenheit seasonal variation, from 35 degrees Fahrenheit in January to 78 degrees Fahrenheit in July.

For the 5-year period recorded, the maximum and minimum monthly temperature in July also varied by 31 degrees Fahrenheit from 64 degrees Fahrenheit to 95 degrees Fahrenheit, and in January by 13 degrees Fahrenheit from 32 degrees Fahrenheit to 45 degrees Fahrenheit.

Data from Lake Michigan at Kenosha, Wisconsin, indicate differences in temperatures within a month of up to 12 degrees Fahrenheit. The annual range of 1964 monthly average temperatures vary from 32 degrees Fahrenheit in February to 66 degrees Fahrenheit in September, an increment of 34 degrees Fahrenheit.

Natural Heat or Energy Cycle

The natural cause of the preceding water temperature variation is the heat or energy exchanges between outer space and the earth and its atmosphere.

MR. STEIN: Pardon. May I interrupt just a moment? You are not reading your whole statement.

Do you want this statement to appear as you have written it in its entirety in the record?

MR. ASCHOFF: Yes, sir.

MR. STEIN: Without objection, this will be done.

(The document referred to above follows in its entirety.)

THERMAL DISCHARGES IN PROPER PERSPECTIVE

A STATEMENT PREPARED FOR THE
FEDERAL-STATE ENFORCEMENT CONFERENCE ON POLLUTION
OF LAKE MICHIGAN AND ITS TRIBUTARIES

SHERMAN HOUSE
CHICAGO, ILLINOIS
SEPTEMBER 28, 1970

SARGENT & LUNDY
ENGINEERS
CHICAGO

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V. SUMMARY

SARGENT & LUNDY
ENGINEERS
CHICAGO

THERMAL DISCHARGES IN PROPER PERSPECTIVE

I. INTRODUCTION

This statement was prepared to help further the understanding of power plant thermal discharges, especially as related to the physical laws of nature and natural behaviour of waters. Through this discussion it is hoped that power plant thermal discharges can be considered in their proper perspective in the broad scope of natural phenomena which are occurring continuously in the universe.

A discussion regarding thermal discharges necessitates a general understanding of the characteristics and behaviour of natural bodies of water. This should include an appreciation of the world's supply of water and its continuing cycle, change in phase, and change in location. Natural variations occur in all natural bodies of water and are the result of many causes. One of these is the heat exchange between the earth and outer space.

With knowledge of the natural behaviour of natural bodies of water, un-natural or manmade influences such as the addition of heat may then be superimposed and their magnitude compared to the natural background phenomena.

Physical characteristics of water such as density, viscosity and vapor pressure, as well as heat transfer, change with temperature. Understanding of these relationships is essential.

The ensuing discussion considers both the general aspects of thermal discharge and behaviour of warmed water and the relationship of these factors to natural waters. Lake Michigan is considered particularly.

II. NATURAL BEHAVIOUR OF ALL NATURAL BODIES OF SURFACE WATER

The Water Cycle

In a broad sense water is never lost. The world supply of water circles endlessly from sky to land to ocean, and then back to sky again. Water rises from the ocean and is carried across the land, partly as invisible vapor and partly as tiny condensed droplets. Some of this moisture in air falls to earth as rain, sleet or hail. There a small amount quickly returns to the ocean as runoff, some goes underground to feed plant roots, or seeps back to the ocean. Most of the water on the earth's surface returns to the atmosphere by evaporation from land, water surfaces and plants. Within this mechanism, Figure 1, the amount of water remains essentially constant. But the way water is distributed in the ocean, in the atmosphere, on and under land, varies from hour-to-hour, day-to-day, and month-to-month.

Variations in Surface Water Temperatures

Temperatures of natural bodies of water are also naturally dynamic. They change as the water flows from one location to the other, from hour-to-hour, between day and night, from month-to-month, and year-to-year.

For example, the temperature of the Mississippi River increases by 5°F, from 75°F to 80°F, in its travel from south of Moline, Illinois to north of Memphis, Tennessee. Estimating this distance as four hundred miles would indicate that natural influences tend to increase the water temperature of a river by 1°F for each eighty miles it travels southward.

Surface water temperatures vary from day-to-night. A twenty-four hour change is called a diurnal variation. It should be noted that the actual magnitude of the diurnal change also varies from day-to-day in a given month. For example in the month of June, 1954 the diurnal change of the Vermilion River in Illinois ranged from 2°F to 12°F.

Natural water temperatures vary month by month and the monthly temperatures may also differ from year-to-year. Data from the Vermilion River shows an average 43°F seasonal variation, from 35°F in January to 78°F, in July. For the five year period recorded, the maximum and minimum monthly temperature in July also varied by 31°F from 64°F to 95°F, and in January by 13°F from 32°F to 45°F.

Data from Lake Michigan at Kenosha, Wisconsin indicate differences in temperatures within a month of up to 12°F. The annual range of 1964 monthly average temperatures vary from 32°F in February to 66°F in September, an increment of 34°F.

These previous examples should illustrate that the surface water environment is dynamic. It continually undergoes variations in flow and temperature due to natural causes. The magnitude of some of these are diurnal variations from 2°F to 12°F within the same month, annual changes of 63°F, and summer monthly variations from year-to-year of 31°F. All of these temperature changes occur without any manmade influence.

Natural Heat or Energy Cycle

The natural cause of the preceding water temperature variation is the heat or energy exchanges between outer space and the earth and its atmosphere.

In the same broad sense that water is never lost, so heat or energy is never lost. Considering all incoming solar radiation, thirty-three percent is reflected and nine percent is scattered back to outer space from the atmosphere. Some fifteen percent is absorbed by the atmosphere and the balance passes to the earth as direct diffuse radiation. Diffuse radiation is direct radiation which has been scattered by atmospheric constituents. This is an average overall balance and, of course, does not indicate daily, seasonal, or local variation.

Variations in Heat Flows

An illustration of the annual variation of solar radiation for different latitudes is shown on Figure 2. The effect of latitudes is greater in the winter months compared to the summer months. For January the average solar energy is 1,000 Btu/sq.ft./day and increases to almost 3,000 Btu/sq.ft./day or an average variation of about 2,000 Btu/sq.ft./day.

A far greater variation occurs during the day when from 6:00 a.m. to 7:00 p.m., on a clear July day, the rate of solar energy for a selected location varied from 0 to a mid-day peak equivalent of 7,200 Btu/sq.ft./day and decreased again to 0. The July average value for Lake Michigan exceeds 2,500 Btu/sq.ft./day.

Therefore, as in the case of the surface water environment, the heat exchange between outer space, atmosphere and the earth's surface is also dynamic. Heat is never lost but the rate at which it is transferred varies from hour-to-hour, day-to-day, and month-to-month.

With this understanding of the natural effects of natural bodies of surface water as a background it is of interest to superimpose and compare the manmade effects onto the natural phenomena.

III. HYDRO-THERMAL EFFECTS OF HEAT DISCHARGE TO SURFACE WATER

Condenser Cooling Water Cycle

Heat rejection from the turbine source leaves the power plant via the condenser cooling water cycle. See Figure 3. Cooling water is generally obtained from a river, a lake, or other large body of water by pumping. After passing through the condenser, the water conveys the heat back to the river, lake or other large body of water. This heated discharge spreads itself over the water surface and the heat is transferred to the air. Although the magnitude of heat is determined by the turbine, the temperature rise of cooling water passing through the condenser will depend on the quantity of water used.

Distinction Between Heat and Temperature

The relationship between temperature and heat is subtle and not always understood.

If 20 Btu's are added to 1 pound of water, the temperature is increased 20°F. So, if water is initially 85°F, it would become 105°F. If the same Btu's are added to 2 pounds of water, the temperature is increased only 10°F and the same 85°F initial temperature of water would be raised only to 95°F. Therefore, different quantities of water passing through the condenser and receiving the identical turbine exhaust heat rejection will have different final water temperatures depending on the quantity of water and its initial temperature. Temperature rise through existing condensers in power plants ranges from 10° to 30°F.

Change in Physical Properties of Water With Change in Temperature

Density is one of the physical characteristics of water that changes with temperature. Density decreases with increasing temperature as shown in Figure 4. Water density or weight at 100°F is 99.3% of the weight of water at 50°F. It is this characteristic that manifests itself by vertical temperature stratification (or layering) in bodies of water. Conclusions reached from many studies on rivers, lakes, and reservoirs substantiate the fact that hot water at lighter density rises to the surface.

The second physical characteristic influenced by temperature is viscosity. Water becomes less viscous at higher temperatures as shown in Figure 5. At 100°F water viscosity is about half that of water at 50°F and is more fluid and slippery. Manifestation of the change in viscosity with temperature occurs in the channeling of hot water discharges. Temperature measurements taken over the surface of Lake Michigan near a power plant discharge in Figure 6 show a defined hot water plume. Because of its lower viscosity the hot water slips by the adjacent cooler water, yielding an overall channeling effect. This same channeling characteristic has been noted in many other rivers, lakes, and reservoirs.

A third physical characteristic that changes with temperature is water vapor pressure as shown in Figure 7. Water vapor pressure influences evaporation. The higher the vapor pressure, the greater the evaporation. The increase in vapor pressure is far more rapid at the higher temperatures of 80 to 100°F then in the range of 40 to 60°F.

Energy Budget of a Body of Water

Having briefly reviewed the change in physical characteristics of water with temperature and the resulting hydraulic effects, let us next consider the energy budget of a body of water. Although a lake will be used to illustrate the phenomena, the principles apply to any body of water including rivers, estuaries or oceans.

The energy budget of a natural lake or other body of water without any industrial heat loading is always tending to maintain a balance. When industrial heat is added, equilibrium is maintained by increases in conduction, evaporation and radiation from the surface.

The industrial heat portion is dissipated by four mechanisms - evaporation, conduction (transfer of sensible heat), radiation and advection. On an annual average, the relative magnitudes are evaporation-40%, conduction-25%, radiation-30%, and advection-5%. However, this relationship varies with seasons and the water temperature.

Heat Dissipation From Water Surface

Plots of heat dissipation from water surface for various water temperatures and a winter and summer month in Figure 8 illustrate two phenomena. First, although the relative magnitudes of advection and radiation are about the same in January and June, the percentage of evaporation is greater and the percentage of conduction less in the summer than winter. The reason for this is the difference in ambient air wet and dry bulb temperatures over the year plotted in Figure 9.

The temperature difference between the hot water discharge from a plant and the wet bulb is the motivation for evaporative heat transfer. This temperature difference is greater in the summer and accounts for the higher evaporation at this time of year.

On the other hand, the motivation for heat transfer by conduction is the difference between the hot water and the dry bulb temperatures. In this case the greater difference and hence greater conduction occurs in the winter months.

This explains the higher evaporation and lower conduction that occurs in the summer months. The other phenomenon illustrated in Figure 8 is the significant increase of heat dissipation from a surface as the water temperature increases. In the month of June each 10°F increase in water temperature almost doubles the quantity of heat dissipated. This indicates that the hotter the water, the sooner the heat is dissipated from the surface area, or, for the same time interval, less surface would be required to dissipate the same quantity of heat. This can be illustrated by comparing the two water surface areas needed to dissipate heat from a 2000 MW plant with hot water discharge temperatures of 100°F and 107°F as shown in Figure 10. In both cases the final temperature is just under 85°F. The surface area required to cool this heat to 85°F from an initial temperature of 100°F is 2700 acres, whereas only 2000 acres is required with the initial temperature of 107°F. The amount of heat rejection for both cases is identical.

If these two cooling curves are plotted for the same surface area as in Figure 11, the portions of surface above various temperatures can be compared. With the 100°F water discharge, 100% of the surface area would be above 85°F and 37% above 90°F. However, if the water discharge is hotter, such as 107°F, only 85% of the surface would be above 85°F and 33% above 90°F. The portion of total surface above 95°F is relatively small for both cases - 15% for the 100°F discharge and 19% for the 107°F discharge.

From this data a further plot of surface area and water temperatures for the 100°F and 107°F discharge can be made as shown in Figure 12. This shows that a larger percentage of water surface area is cooler with a hotter water discharge. For example, with the 107°F discharge, over 80% of the surface is cooler than with the 100°F discharge. Therefore, if it is the objective to keep the majority of surface water at as low a temperature as possible, the hotter the thermal discharge the better.

IV. INFLUENCE OF NON-NATURAL HEAT DISCHARGES ON NATURAL BEHAVIOUR OF NATURAL WATERS

Modern steam turbine-generators have the highest efficiency of all heat machines in practical use today. Fossil fuel steam electric stations utilizing steam pressures from 2000 to 3500 psi at temperatures of 1000°F have an overall thermal efficiency of 37 to 38%. Nuclear fueled plants operating at somewhat lower pressures of 1000 psi and 600°F temperature attain a thermal efficiency of 33%. These thermal efficiencies are still significantly higher than other heat machines in use today such as gas turbines at 20% and automobile engines at 10%. The higher the efficiency the less waste heat discharged.

The magnitude of heat rejection from a steam turbine is related to the inlet steam pressure and temperature and the exhaust pressure as shown in Figure 13. Exhaust pressure is a function of cooling water temperature. The higher the temperature, the higher the exhaust pressure and hence the higher the heat discharge. For the three steam cycles in common use today the heat rejection ranges from 4000 Btu/Kwh generation to 7300 Btu/Kwh generation.

Cooling water from Lake Michigan has a lower temperature than water cooled by alternate means, such as cooling towers. Therefore, steam cycles utilizing Lake Michigan cooling water are more efficient. This results in conservation of energy and permits lower thermal discharge to the surroundings.

Although many power generating facilities have been built on Lake Michigan, it is interesting to note that long term temperature trends for Lake Michigan indicate a gradual decrease in mean annual water temperatures. Earliest records at Milwaukee, Wisconsin, dating from 1875, indicate a mean annual temperature of about 48°F. Temperatures have been gradually falling since then. Recent records indicate a mean annual temperature of only about 43°F. This strongly suggests that man-made thermal effects are non-cumulative.

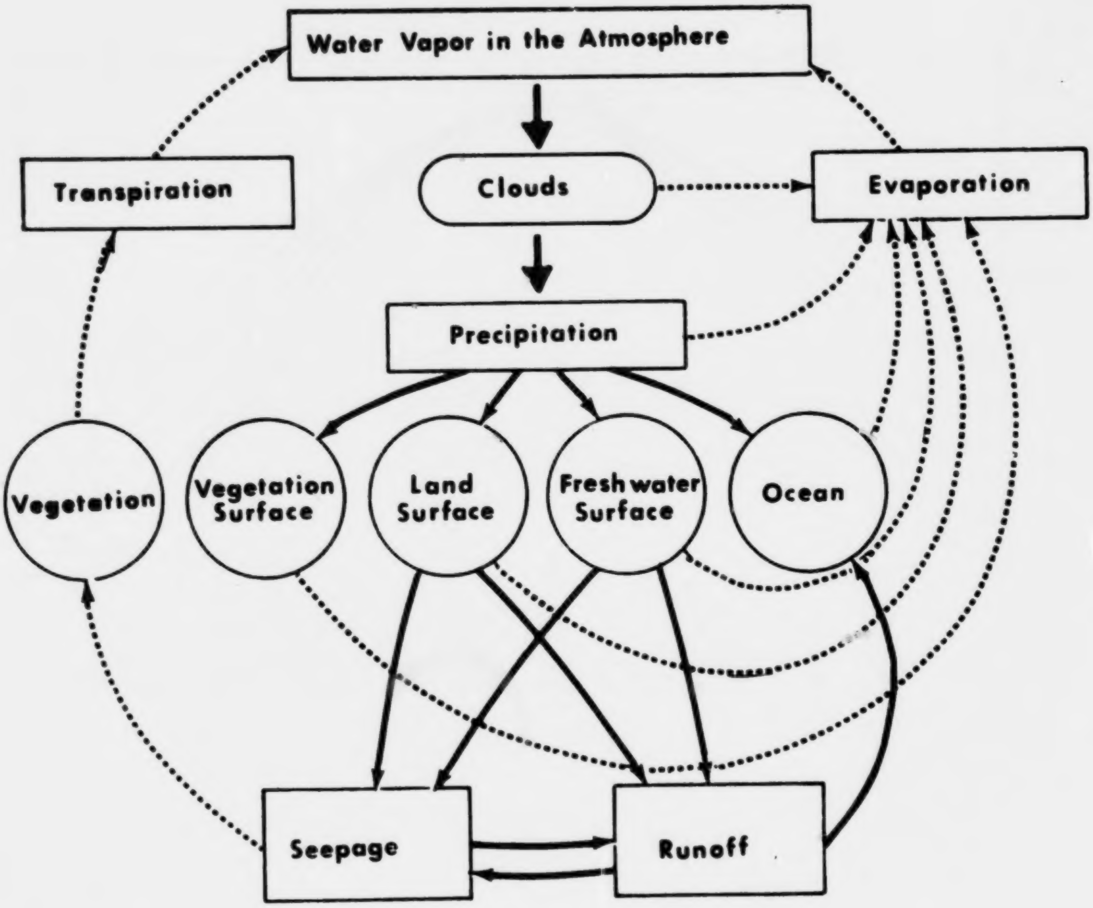
V. SUMMARY

In summary, we have investigated the influence of natural variations on the thermal behaviour of water. Many examples were cited which demonstrated widely varying temperatures related to variations in solar radiation and stream flow, and to seasonal and climatic effects.

The power plant heat cycle was reviewed to assess its contribution to that of nature.

We have seen that there are several physical properties of water such as density, viscosity, and vapor pressure, which aid in heat removal by increasing heat lost by evaporation. In the case of Lake Michigan, annual temperatures have been decreasing. This indicates that man-made heat has a non-cumulative effect.

We have also learned that neither water or heat is ever completely lost, only displaced. We note that heat transfer is accelerated by higher discharge temperatures, resulting in less water area affected. Finally, we see that use of Lake Michigan water for direct cooling results in more efficiency and less heat loss to the surroundings.


Water Vapor in the Atmosphere
Transpiration
Clouds
Evaporation
Precipitation
Vegetation
Vegetation Surface
Land Surface
Fresh water Surface
Ocean
Seepage
Runoff

The World of Water

Figure 1

CLEAR SKY SOLAR RADIATION
(After Koberg, 1962)

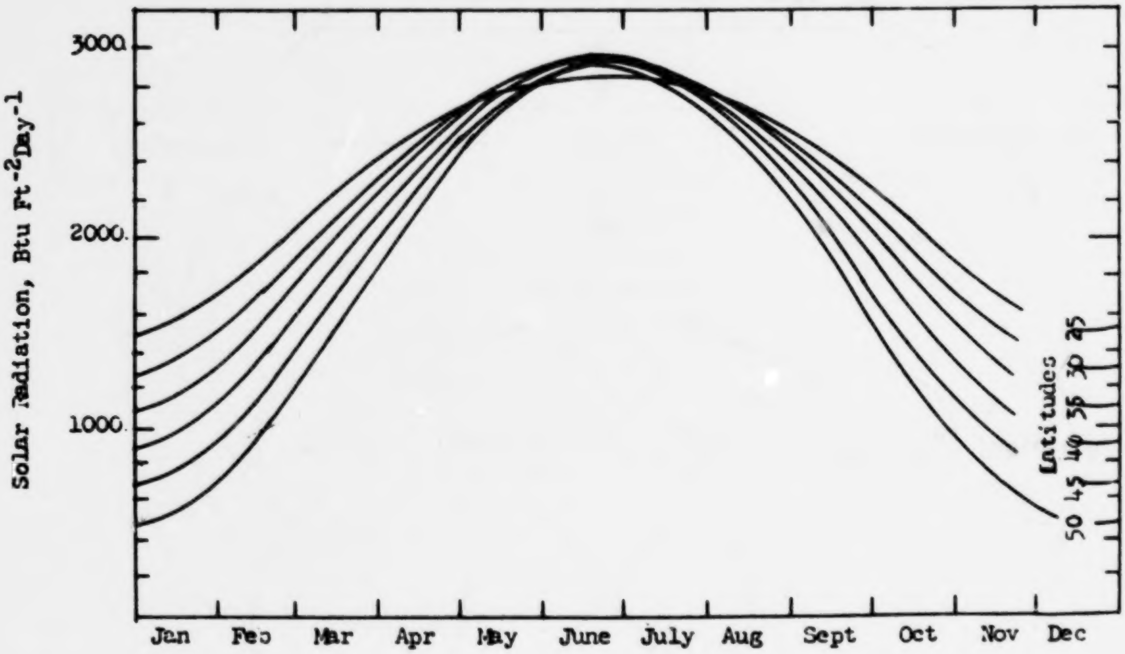


Figure 2

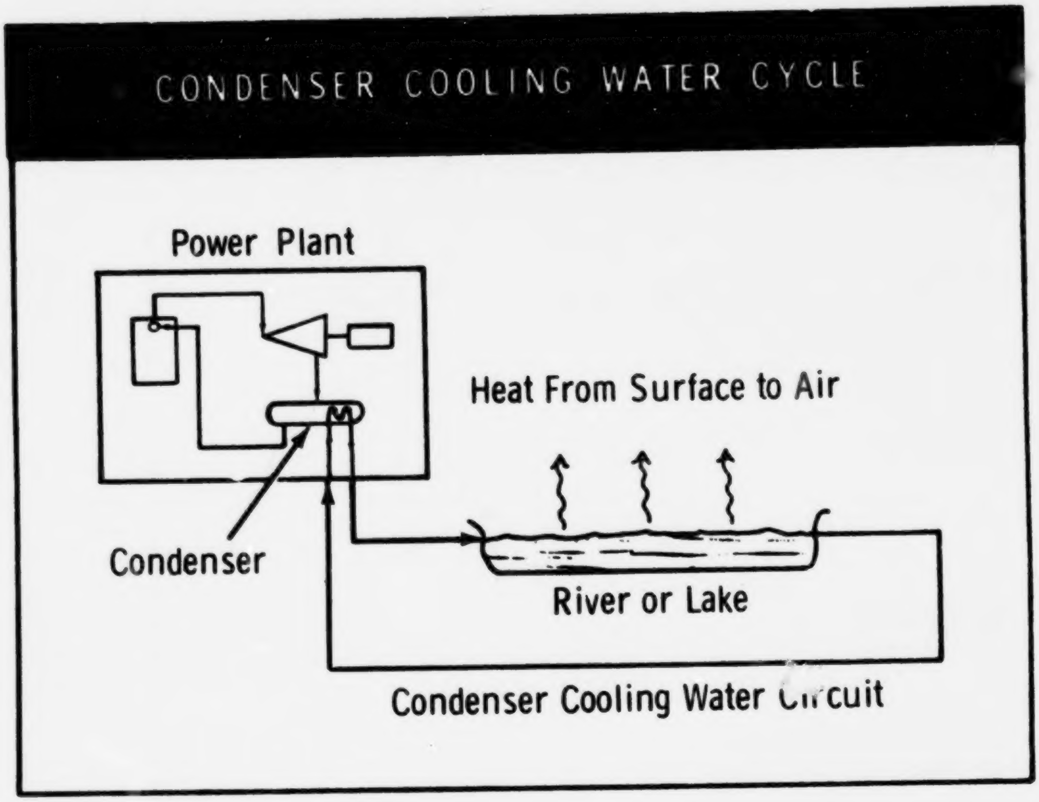
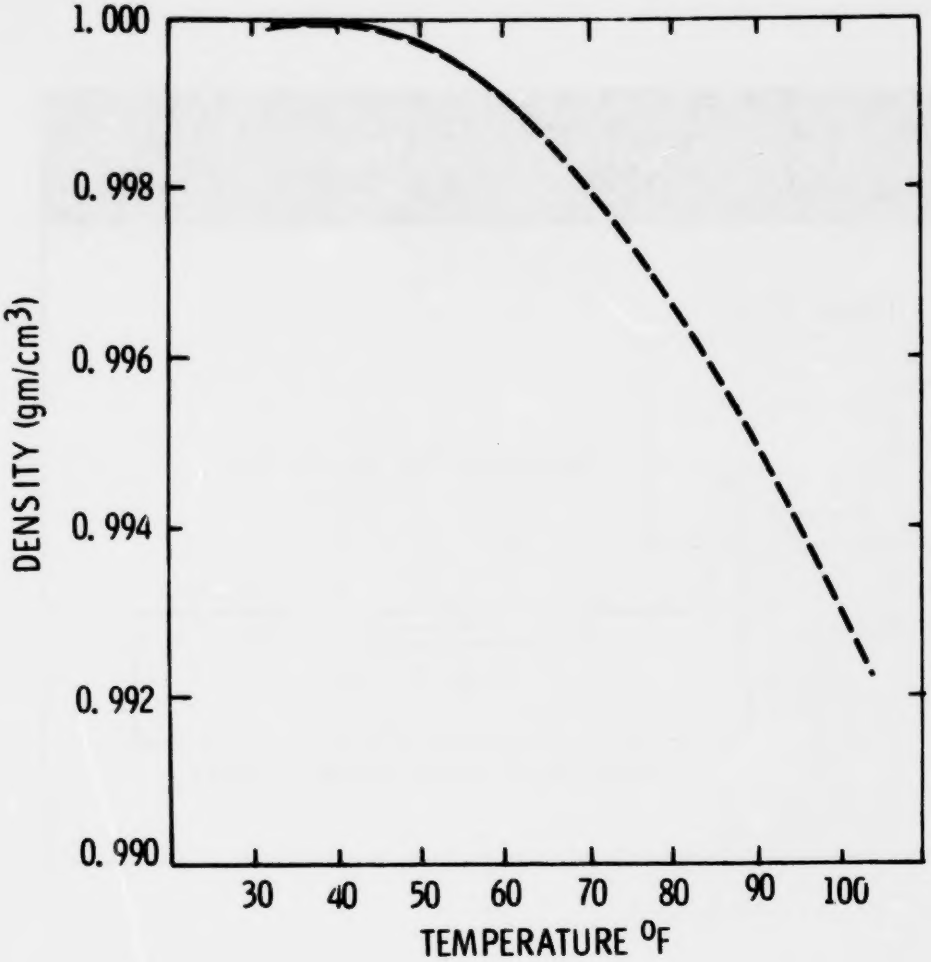
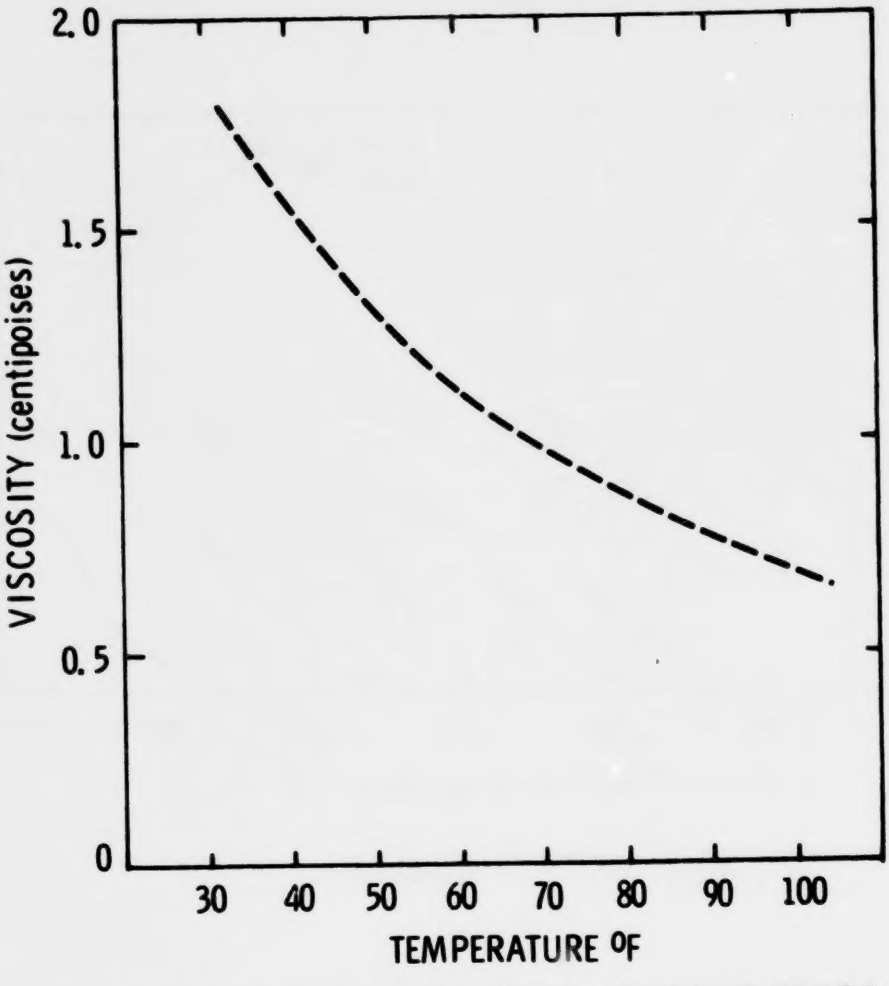

CONDENSER COOLING WATER CYCLE
Power Plant
Heat From Surface to Air
Condenser
River or Lake
Condenser Cooling Water Circuit

Figure 3



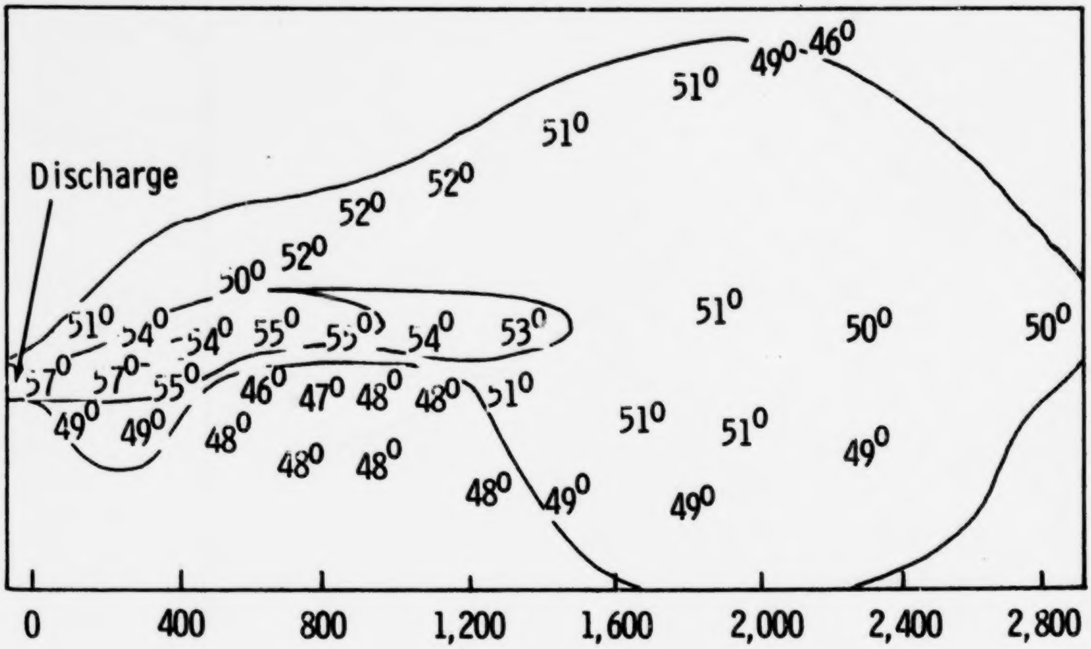
DENSITY CHANGES WITH TEMPERATURE

Figure 4



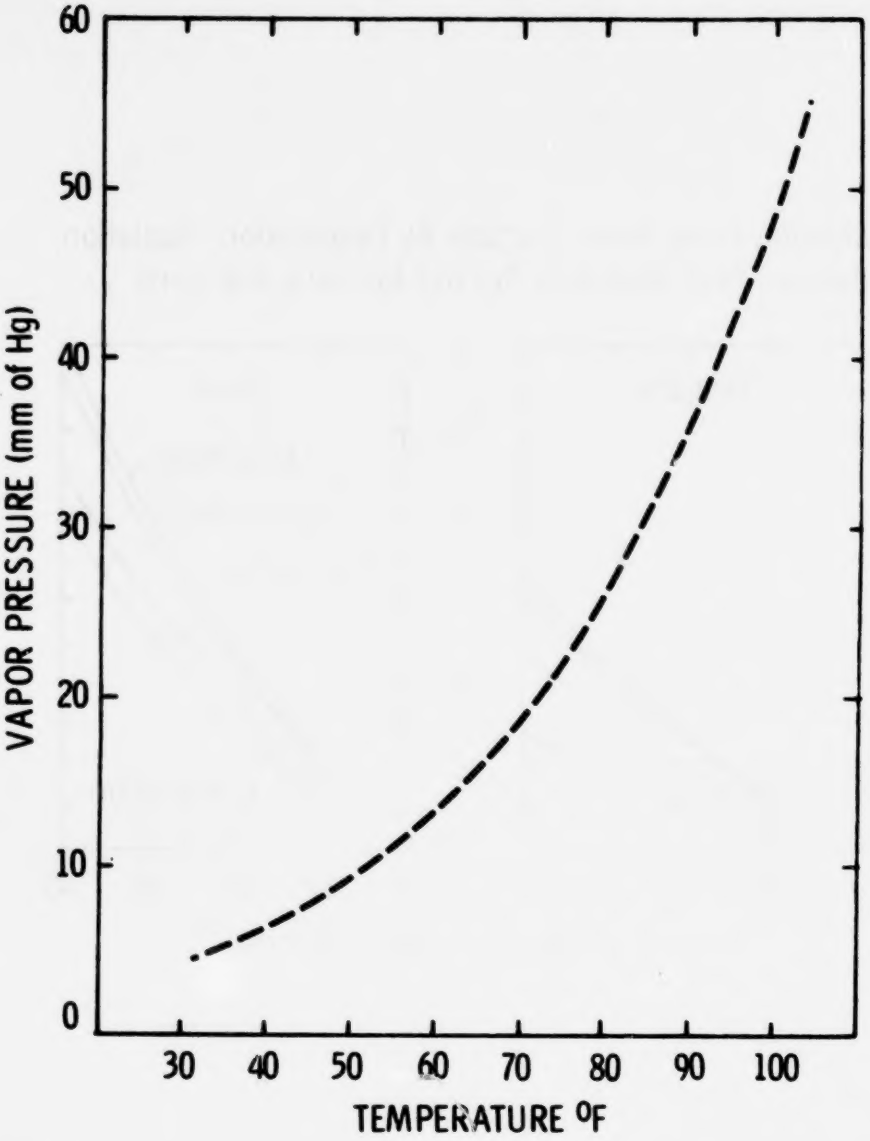
VISCOSITY CHANGES WITH TEMPERATURE

Figure 5



WARM WATER CHANNELING

Figure 6



VAPOR PRESSURE CHANGES WITH TEMPERATURE

Figure 7

Heat Dissipation From Water Surface By Evaporation, Radiation, Conduction And Advection During January And June

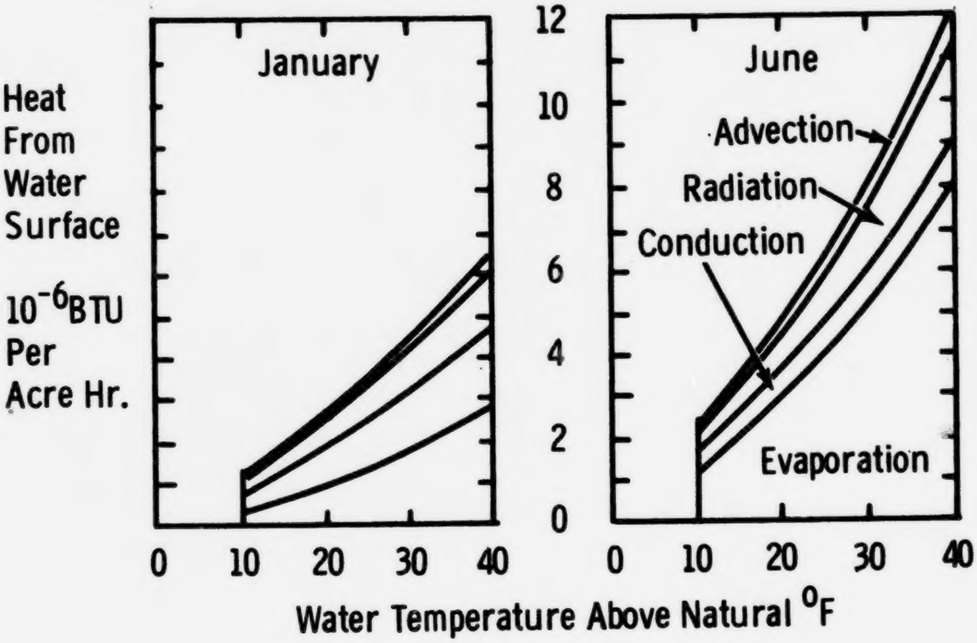
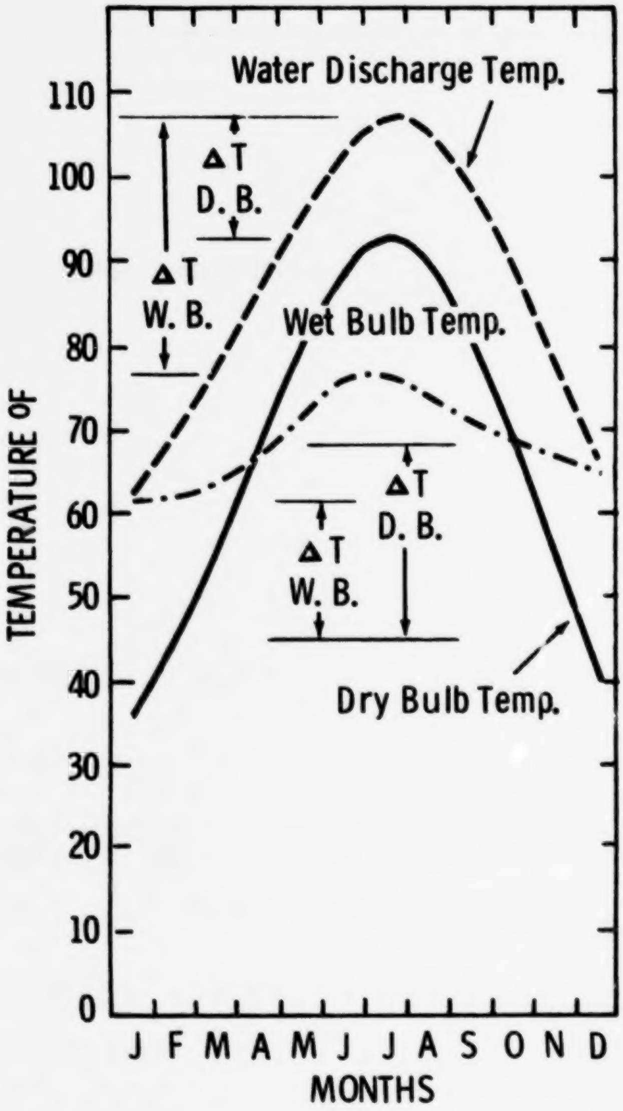
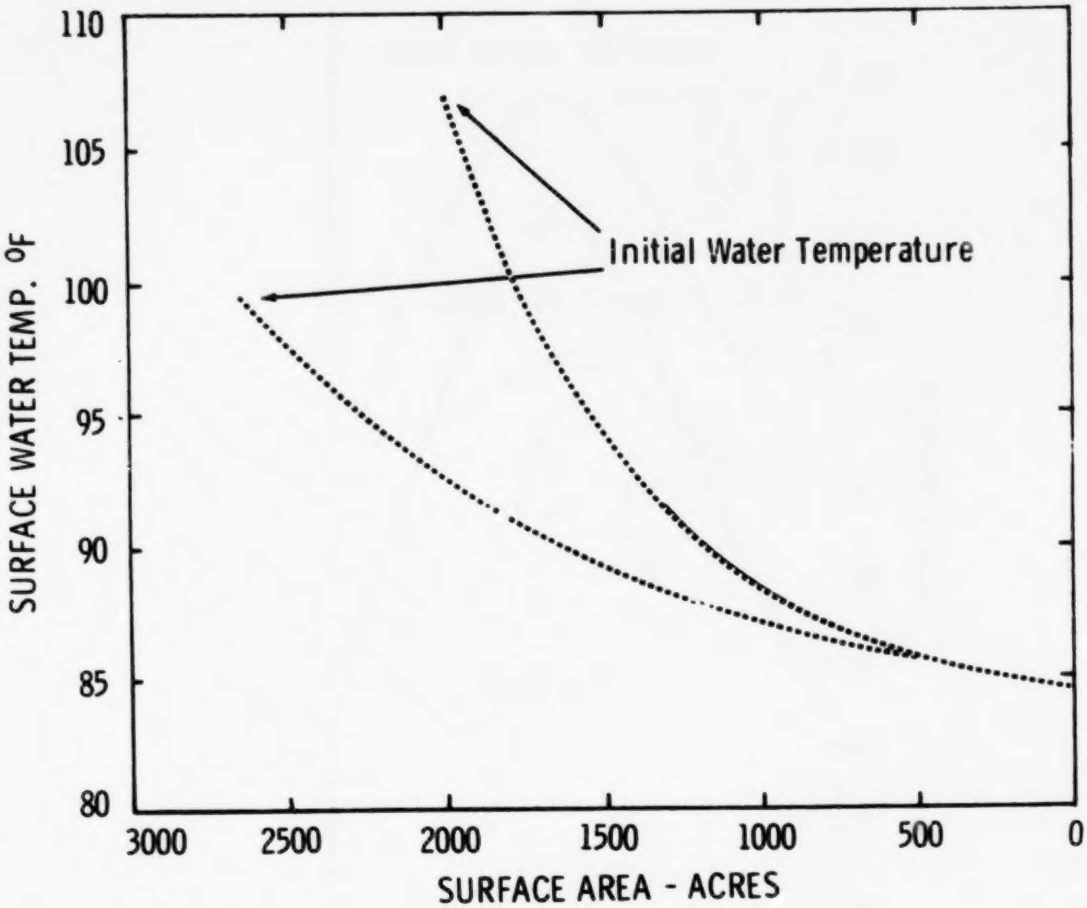


Figure 8



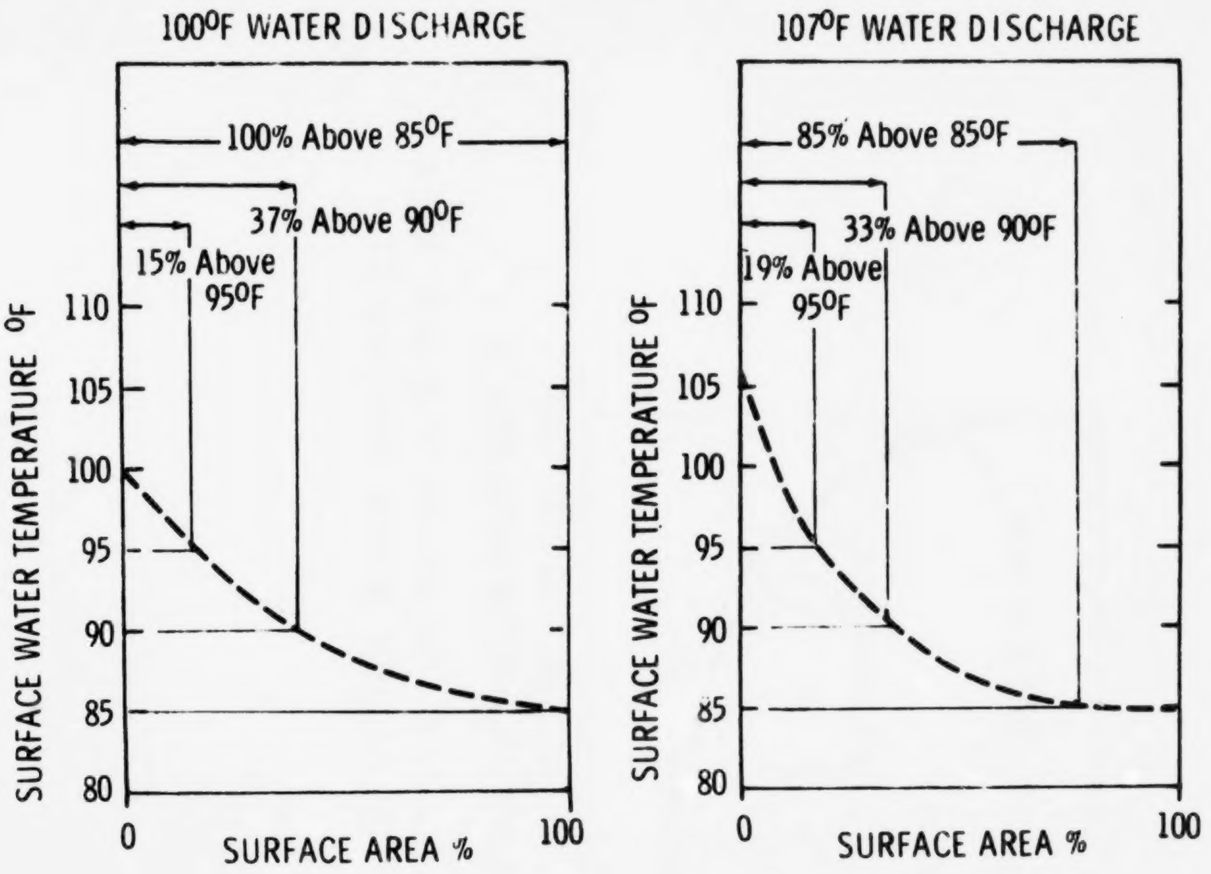
COMPARISON OF ΔT TO SEASONAL WET BULB AND DRY BULB TEMPERATURES

Figure 9



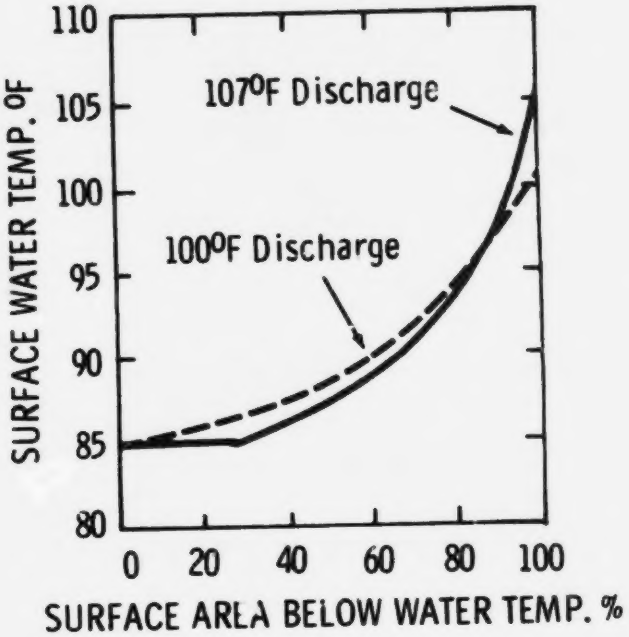
SURFACE AREA REQUIRED TO REJECT IDENTICAL HEAT AT DIFFERENT INITIAL WATER TEMPERATURES

Figure 10



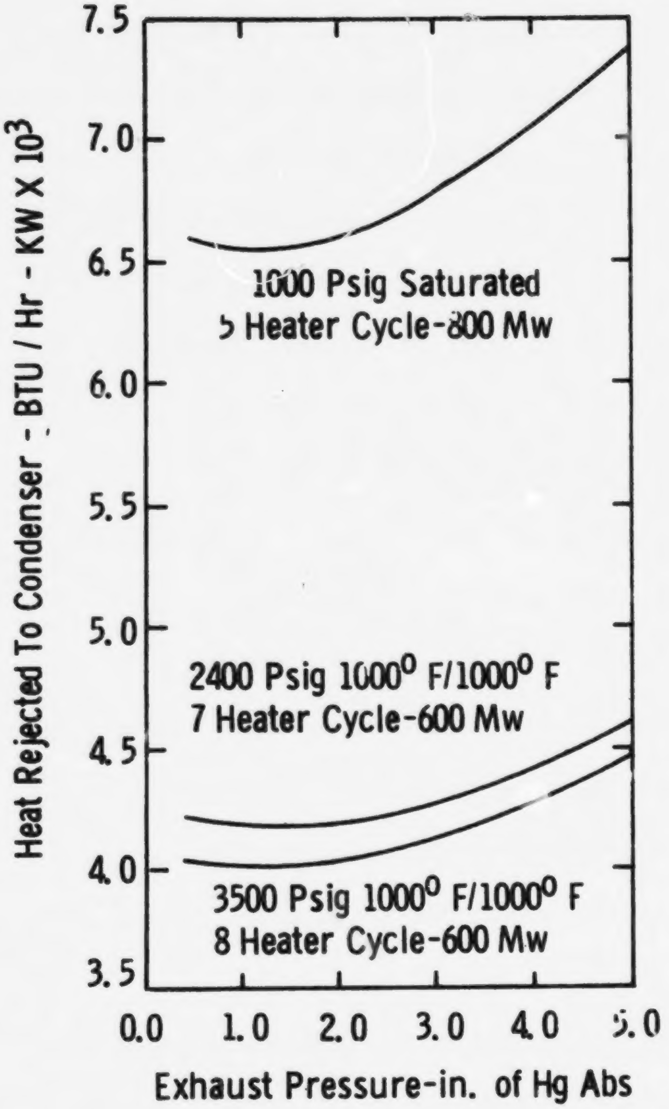
PERCENT OF SURFACE AREA ABOVE VARIOUS WATER TEMPERATURES FOR 100°F & 107°F DISCHARGE

Figure 11



LARGER PERCENTAGE OF WATER SURFACE AREA COOLER WITH HOTTER WATER DISCHARGE

Figure 12



COMPARISON OF CONDENSER HEAT REJECTION FOR
THREE TYPICAL CYCLES

Figure 13

A. F. Aschoff

MR. ASCHOFF: In the same broad sense that water is never lost, so heat or energy is never lost. Considering all incoming solar radiation, 33 percent is reflected and 9 percent is scattered back to outer space from the atmosphere. Some 15 percent is absorbed by the atmosphere and the balance passes to the earth as direct diffuse radiation. Diffuse radiation is direct radiation which has been scattered by atmospheric constituents. This is an average overall balance and, of course, does not indicate daily, seasonal, or local variation.

Variations in Heat Flows

An illustration of the annual variation of solar radiation for different latitudes is shown on Figure 2. (See P. 638) The effect of latitudes is greater in the winter months compared to the summer months. For January the average solar energy is 1,000 B.t.u./sq.ft./day and increases to almost 3,000 B.t.u./-sq.ft./day or an average variation of about 2,000 B.t.u./-sq.ft./day.

A far greater variation occurs during the day when from 6:00 a.m. to 7:00 p.m., on a clear July day, the rate of solar energy for a selected location varied from zero to a mid-day peak equivalent of 7,200 B.t.u./-sq.ft./day and decreased again to zero. The July average value for Lake Michigan exceeds 2,500 B.t.u./sq.ft./day.

Therefore, as in the case of the surface water environment, the heat exchange between outer space, atmosphere and the earth's surface is also dynamic. Heat is never lost but the rate at which it is transferred varies from hour-to-hour, day-to-day, and month-to-month.

With this understanding of the natural effects of natural bodies of surface water as a background it is of interest to superimpose and compare the manmade effects onto the natural phenomena.

III. Hydro-Thermal Effects of Heat Discharge to Surface Water

Condenser Cooling Water Cycle

Heat rejection from the turbine source leaves the power plant via the condenser cooling water cycle. See Figure 3. (See P. 639) Cooling water is generally obtained from a river, a lake, or other large body of water by pumping. After passing through the condenser, the water conveys the heat back to the river, lake, or other large body of water. This heated discharge spreads itself over the water surface and the heat is transferred to the air. Although the magnitude of heat is determined by the turbine, the temperature rise of cooling water passing through the condenser will depend on the quantity of water used.

Distinction Between Heat and Temperature

The relationship between temperature and heat is subtle and not always understood.

If 20 B.t.u.'s are added to 1 pound of water, the temperature is increased 20 degrees Fahrenheit. So, if water is initially 85 degrees Fahrenheit, it would become 105 degrees Fahrenheit. If the same B.t.u.'s are added to 2 pounds of water, the temperature is increased only 10 degrees Fahrenheit and the same 85 degree Fahrenheit initial temperature of water would be raised only to 95 degrees Fahrenheit. Therefore, different quantities of water passing through the condenser and receiving the identical turbine exhaust heat rejection will have different final water temperatures depending on the quantity of water and its initial temperature. Temperature rise through existing condensers in powerplants ranges from 10 degrees to 30 degrees Fahrenheit.

Change in Physical Properties of Water with Change in Temperature

Density is one of the physical characteristics of water that changes with temperature. Density decreases with increasing temperature as shown in Figure 4. (See P. 640) Water density or weight at 100 degrees Fahrenheit is 99.3 percent of the weight of water at 50 degrees Fahrenheit. It is this characteristic that manifests itself by vertical temperature stratification (or layering) in bodies of water. Conclusions reached from many studies on rivers, lakes, and reservoirs substantiate the fact that hot water at lighter density rises to the surface.

The second physical characteristic influenced by temperature is viscosity. Water becomes less viscous at higher temperatures as shown in Figure 5. (See P. 641) At 100 degrees Fahrenheit water viscosity is about half that of water at 50 degrees Fahrenheit and is more fluid and slippery. Manifestation of the change in viscosity with temperature occurs in the channeling of hot water discharges. Temperature measurements taken over the surface of Lake Michigan near a powerplant discharge in Figure 6 (See P. 642) show a defined hot water plume. Because of its lower viscosity the hot water slips by the adjacent cooler water, yielding an overall channeling effect. This same channeling characteristic has been noted in many other rivers, lakes, and reservoirs.

A third physical characteristic that changes with temperature is water vapor pressure as shown in Figure 7. (See P. 643) Water vapor pressure influences evaporation. The higher the vapor pressure, the greater the evaporation. The increase in vapor pressure is far more rapid at the higher temperatures of 80 to 100 degrees Fahrenheit than in the range of 40 to 60 degrees Fahrenheit.

Energy Budget of a Body of Water

Having briefly reviewed the change in physical characteristics of water with temperature and the resulting hydraulic effects, let us next consider the energy budget of a body of water. Although a lake will be used to illustrate the phenomena, the principles apply to any body of water including rivers, estuaries or oceans.

The energy budget of a natural lake or other body of water without any industrial heat loading is always tending to maintain a balance. When industrial heat is added, equilibrium is maintained by increases in conduction, evaporation and radiation from the surface.

On an annual average, the relative magnitudes are evaporation, 40 percent; conduction, 25 percent; radiation, 30 percent; and advection, 5 percent. However, this relationship varies with seasons and the water temperature.

Heat Dissipation from Water Surface

Plots of heat dissipation from water surface for various water temperatures and a winter and summer month in Figure 8 (See P. 644) illustrate two phenomena. First, although the relative magnitudes of advection and radiation are about the same in January and June, the percentage of evaporation is greater and the percentage of conduction less in the summer than winter. The reason for this is the difference in ambient air wet and dry bulb temperatures over the year plotted in Figure 9. (See P. 645)

The temperature difference between the hot water discharge from a plant and the wet bulb is the motivation for evaporative heat transfer. This temperature difference is greater in the summer and accounts for the higher evaporation at this time of year.

On the other hand, the motivation for heat transfer by conduction is the difference between the hot water and the dry bulb temperatures. In this case, the greater difference and hence greater conduction occurs in the winter months.

This explains the higher evaporation and lower conduction that occurs in the summer months. The other phenomenon illustrated in Figure 8 (See P. 644) is the significant increase of heat dissipation from a surface as the water temperature increases. In the month of June each 10-degree-Fahrenheit increase in water temperature almost doubles the quantity of heat dissipated. This indicates that the hotter the water, the sooner the heat is dissipated from the surface area, or, for the same time interval, less surface would be required to dissipate the same quantity of heat. This can be illustrated by comparing the two water surface areas needed to dissipate heat from a 2,000 MW plant with hot water discharge temperatures of 100 degrees Fahrenheit and 107 degrees Fahrenheit as shown in Figure 10. (See P. 646) In both cases the final temperature is just under 85 degrees Fahrenheit. The surface area required to cool this heat to 85 degrees Fahrenheit from an initial temperature of 100 degrees Fahrenheit is 2,700 acres, whereas only 2,000 acres is required with the initial temperature of 107 degrees Fahrenheit. The amount of heat rejection for both cases is identical.

If these two cooling curves are plotted for the same surface area as in Figure 11 (See P. 647), the portions of surface above various temperatures can be compared. With the 100 degree Fahrenheit water discharge, 100 percent of the surface area would be above 85 degrees Fahrenheit and 37 percent above 90 degrees Fahrenheit. However, if the water discharge is hotter, such as 107 degrees Fahrenheit, only 85 percent of the surface would be above 85 degrees Fahrenheit and 33 percent above 90 degrees Fahrenheit. The portion of total surface above

95 degrees Fahrenheit is relatively small for both cases: 15 percent for the 100 degree Fahrenheit discharge and 19 percent for the 107 degree Fahrenheit discharge.

From this data a further plot of surface area and water temperatures for the 100 degree Fahrenheit and 107 degree Fahrenheit discharge can be made as shown in Figure 12 (See P. 648) This shows that a larger percentage of water surface area is cooler with a hotter water discharge. For example, with the 107 degree Fahrenheit discharge, over 80 percent of the surface is cooler than with the 100 degree Fahrenheit discharge. Therefore, if it is the objective to keep the majority of surface water at as low a temperature as possible, the hotter the thermal discharge the better.

IV. Influence of Non-Natural Heat Discharges on Natural Behavior of Natural Waters

Modern steam turbine-generators have the highest efficiency of all heat machines in practical use today. Fossil fuel steam electric stations utilizing steam pressures from 2,000 to 3,500 p.s.i. at temperatures of 1,000 degrees Fahrenheit have an overall thermal efficiency of 37 to 38 percent. Nuclear fueled plants operating at somewhat lower pressures of 1,000 p.s.i. and 600 degrees Fahrenheit temperature attain a thermal efficiency of

33 percent. These thermal efficiencies are still significantly higher than other heat machines in use today such as gas turbines at 20 percent and automobile engines at 10 percent. The higher the efficiency the less waste heat discharged.

The magnitude of heat rejection from a steam turbine is related to the inlet steam pressure and temperature and the exhaust pressure as shown in Figure 13. (See P. 649) Exhaust pressure is a function of cooling water temperature. The higher the temperature, the higher the exhaust pressure and hence the higher the heat discharge. For the three steam cycles in common use today the heat rejection ranges from 4,000 B.t.u./Kwh generation to 7,300 B.t.u./Kwh generation.

Cooling water from Lake Michigan has a lower temperature than water cooled by alternate means, such as cooling towers. Therefore, steam cycles utilizing Lake Michigan cooling water are more efficient. This results in conservation of energy.and permits lower thermal discharge to the surroundings.

Although many power generating facilities have been built on Lake Michigan, it is interesting to note that long-term temperature trends for Lake Michigan indicate a gradual decrease in mean annual water temperatures.

Earliest records at Milwaukee, Wisconsin, dating from 1875, indicate a mean annual temperature of about 48 degrees Fahrenheit. Temperatures have been gradually falling since then. Recent records indicate a mean annual temperature of only about 43 degrees Fahrenheit. This strongly suggests that manmade thermal effects are noncumulative.

V, Summary

In summary, we have investigated the influence of natural variations on the thermal behavior of water. Many examples were cited which demonstrated widely varying temperatures related to variations in solar radiation and stream flow, and to seasonal and climatic effects.

The powerplant heat cycle was reviewed to assess its contribution to that of nature.

We have seen that there are several physical properties of water such as density, viscosity, and vapor pressure, which aid in heat removal by increasing heat loss by evaporation. In the case of Lake Michigan, annual temperatures have been decreasing. This indicates that manmade heat has a noncumulative effect.

We have also learned that neither water or heat is ever completely lost, only displaced. We note that heat transfer is accelerated by higher discharge temperatures, resulting in less water area affected. Finally, we see that use of Lake Michigan water for direct cooling results in more efficiency and less heat loss to the surroundings.

This concludes my presentation.

The next paper will be presented by Mr. R. W. Patterson.

MR. STEIN: Let's see if the panel has any comment.

MR. CURRIE: Yes, Mr. Chairman, one question.

MR. STEIN: Yes, Mr. Currie.

MR. CURRIE: You are in favor, I take it, as you say on page 9, of keeping the thermal discharge as hot as possible in order to reduce mixing?

MR. ASCHOFF: In order to get the increase necessary in evaporation, this is the most efficient from an engineering standpoint.

MR. CURRIE: And any mixing that takes place with the surface waters in your view would retard evaporation and therefore be undesirable, is that right?

MR. ASCHOFF: That is right.

MR. CURRIE: So that you disagree with the statement of Dr. Pritchard on behalf of Commonwealth Edison Company in which he says very clearly that in his opinion maximum mixing will minimize the area of the lake affected by actual powerplant discharges up to -- well, above 1 degree Fahrenheit. Are you familiar with that statement?

MR. ASCHOFF: No, I am not.

MR. CURRIE: Well, I think it would be helpful at some point if we could have a little meeting of the minds between the people of the power industry as to which is the better means of disposing of heat. You seem to be saying you want to concentrate it all in one place and Edison seems to be saying it wants it spread around as much as possible, and I would think it helpful if at some point you could give us your comments on Dr. Pritchard's paper, which seems to me to take a very different view from yours upon this question.

MR. ASCHOFF: Well, I would like to have an opportunity to review that before we could submit comments, but we were speaking from our experience with primarily manmade lakes for cooling, in which we note the rapid rise of water to the surface, in which the maximum heat transfer, then, occurs by evaporation.

MR. STEIN: Are there any other comments?

MR. MAYO: Yes, I have a question, Mr. Chairman.

On your page 10, Mr. Aschoff, you make reference to the temperature observations on a long-term basis for Lake Michigan, dropping from 48 degrees to the diurnal of only about 43, and then you have reached the conclusion that this strongly suggests that manmade thermal effects are noncumulative.

MR. ASCHOFF: Yes, sir.

MR. MAYO: Do you have anything upon which -- any basis upon which you could make an evaluation that if it had not been for manmade thermal effects, the temperature in Lake Michigan might be 42 degrees instead of 43?

MR. ASCHOFF: No, sir, I don't. But I am taking my data from Dr. Acres' paper that was presented a few years ago in which he attributes the decline in temperature to things such as storm fronts and increased differences in climatic effects. There is no mention made in that paper of manmade influence.

MR. MAYO: So, as I would take your response, it appears that the data upon which you made your observation may not have included any significant consideration of manmade temperature.

MR. ASCHOFF: I would assume if there was any appreciable cumulative effect of manmade influences that they would have been manifested by an increase of temperature rate rather than a decrease. I think that is a rather logical assumption.

MR. MAYO: If we were in a general period of temperature decline or whatever the variety of contributing factors might be, could the rate of decline of temperature have been impacted by manmade heat contributions? If the answer is yes, then your observation that the manmade thermal effects are noncumulative would not be correct.

MR. ASCHOFF: Do you feel that they are cumulative?

MR. MAYO: No. I am asking the question, that if the evaluation on which you base your conclusion didn't take into account manmade temperature inputs --

MR. ASCHOFF: It was based entirely on Dr. Acres' paper, plus what I felt was a logical conclusion to the results of that paper.

MR. MAYO: You don't know whether Dr. Acres took into account manmade contributions?

MR. ASCHOFF: I don't believe he did.

MR. MAYO: And whether or not manmade contributions would have impact on the rate of otherwise natural decline in temperature.

MR. ASCHOFF: I don't recall reading in his paper any discussion on manmade influences.

MR. STEIN: Any other comments or question?

Mr. Aschoff, you surely have opened another interesting avenue. As I understand it, maybe you are suggesting we are operating on the wrong wavelength here in trying to keep this water as cool as possible. Maybe the trick is to get it as hot as possible, and if we run around the plant long enough, get it pretty close to 21 degrees before we discharge it, we might be able to have ice skating in the lake all year-round.

MR. ASCHOFF: Well, I was attempting to demonstrate the engineering aspects of it rather than the ecological.

MR. STEIN: Well, if your theory is correct, though, why don't you just run it through a closed system until it gets near to boiling, and then put it out and it will hardly have any effect if the hotter you get it the less it is going to affect the lake?

MR. ASCHOFF: We will have to consider it.

MR. STEIN: Right. Thank you.

MR. ASCHOFF: Are there any other questions?

MR. STEIN: No, I don't think so. We are holding the public questions until the power industry is completed. As I pointed out, in the interest of saving time, we are just going to let the panel have questions. Then we will open this to public discussion after all of the power companies are completed.

May we go on with the next one, please?

MR. ASCHOFF: I would like to introduce the next paper if I might.

My paper will be followed by the paper by Mr. R. W. Patterson, who is the Manager of the Mechanical Department, Sargent and Lundy Engineers. The title of his paper is "Preliminary Comments on U. S. Department of the Interior Reports on Lake Michigan Issued in September 1970."

Mr. Patterson.

STATEMENT OF R. W. PATTERSON, MANAGER MECHANICAL DEPARTMENT, SARGENT AND LUNDY ENGINEERS, CHICAGO, ILLINOIS

MR. PATTERSON: Mr. Chairman, members of the conference, ladies and gentlemen.

The two documents prepared by the Department --

MR. STEIN: Would you care to announce your name, again, sir?

MR. PATTERSON: R. W. Patterson.

The two documents prepared by the U. S. Department of the Interior have been available for review for only about a week, and certainly detailed comments on these documents at this time must be somewhat less than definitive, not only because of the very few days since their release, but also because of the lack of ready accessibility to the many references and data used by the Department in the preparation of the report. It has been impossible to study much of the data in sufficient detail to determine whether it is or is not questionable. Therefore, these comments have to be brief.

Our general impression is that to support their conclusions, the Department of the Interior has overstated the effects that powerplant heat will have on Lake Michigan, and at the same time has minimized the problems and effects of the alternate means of cooling.

I would like to expand on these points and also discuss the effect that the imposing of "alternate means" on the utilities would have on plants already under construction.

The main emphasis in the whole report is on the effects of heat on the lake in the year 2000. To arrive at the data for that year reference is made to the "Acres Report," which bases its projection on the estimated electrical power requirements for the midwest area. In other words, it is assumed that plants will be put on Lake Michigan in proportion to the power growth. It is quite obvious, however, that the governmental regulating bodies are not likely to approve unrestricted building of powerplants on Lake Michigan for the next 30 years. Also no consideration is given to the fact that there will be no technological improvements, which will increase the efficiency and thus lower the heat output of powerplants.

Therefore, the heat loads and water flows extrapolated to 2000 will never occur. This data should not be used as a reason for imposing restrictions on plants now under construction or those proposed for the next few years.

One example of the exaggeration that results from looking at the year 2000 is the figure of heat injected by powerplants as compared to the heat from the sun. The report concludes that the powerplant heat will amount to 12.6 percent of that from the sun by the year 2000. If only the existing plants, plus those now under construction and which will be completed in the next 5 years are included, the percentage is only between 2 and 3 percent.

Even the 2 to 3 percent figure is based on all of the plants operating at 100 percent load for 100 percent of the time. This just doesn't happen. We question why the Department increased the capacity factor from the more realistic 60 percent to 80 percent used by Acres.

The heat from powerplants is assumed to be concentrated in the "beach water zone," or an average of about 1 mile from shore. Just extending this to only the so-called "inshore waters" would increase the area threefold, and reduce the average heat input to 1/3. This seems more reasonable because of the statement that so-called "thermal bar" separates the "inshore waters" from the rest of the lake. But even the inshore waters will lose heat to the atmosphere and to the main body of the lake. The report recognizes that their arbitrary zone of heating is "subject to criticism." This is one statement in the report with which we wholeheartedly agree. When stating that "some" of the waste heat will diffuse beyond the 1-mile limit, and "some" will be lost to the air, it is essential to find out whether "some" means "little" or "much."

The volumes of water taken through powerplant condensers is brought out in the report, and has been given considerable emphasis in the press. Although the flows may be large, we must put them into perspective. Remember that Lake Michigan is an extremely large body of water containing 173 billion cubic feet. The Department of the Interior report estimates a total flow through all of the powerplants on Lake Michigan to be 22,364 c.f.s. by 1980. In relation to the total lake, this would be equivalent of about 2 or 3 drops of water in a bucket per day.

Some of the problems of alternate cooling methods are not, in our opinion, given full consideration. It is imperative that in attempting to alleviate one condition that the alternative does not become an equally or even greater problem.

Potential fog problems from cooling towers are covered by the Department's report in detail, but the conclusion is that there will not be much of a problem.

MR. STEIN: While these slides are coming on, Mr. Patterson, if you want these in the record, the slides you have put in your report just don't reproduce, so unless we get negatives or better prints, we will just get a blur.

MR. PATTERSON: We can furnish you with them. These were done rather hurriedly, I believe.

MR. STEIN: Thank you.

MR. PATTERSON: Figure 1 (See P. 670) indicates that under certain weather conditions, vapor plumes can certainly be significant and affect the environment. Plants now under construction cannot be located where prevailing winds would tend to keep the fog away from highways and communities. In addition, there are daily wind patterns induced by the lake itself, which are not considered by the Department of the Interior.

The estimated costs prepared by the Department's

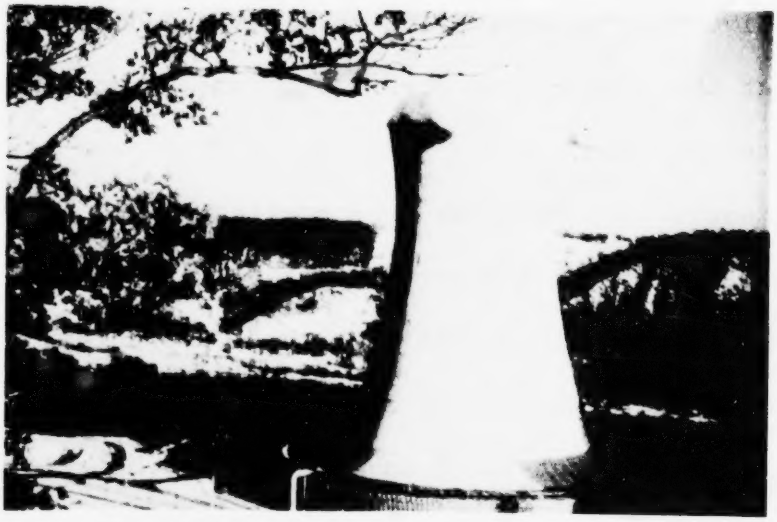


FIGURE 1

FIGURE 2

consultants for each type of auxiliary cooling system are well below the estimates we have made for various locations. The costs presented were apparently gleaned from magazine articles and information given by equipment manufacturers, and then put together by people who have, as far as we can determine, little background of design or construction. We question whether adequate consideration has been given to structures, to support towers, piping, controls, and instrumentation, electrical work, and realistic construction costs including labor rates which would be in effect at the time the systems would be installed. In addition, the costs per kilowatt hour apparently do not fully recognize the lower efficiency when using a different cooling system or the cost of adding more capacity to compensate loss of output.

Originally it was my intention to go no further in trying to compare costs. However in response to the question raised yesterday by the conferee from Wisconsin, Mr. Mackie, I will try to expand on this subject.

My hesitation in getting specific is due only to the fact that the Interior report gives very little detail, and I don't want to challenge anything without substantiation. In addition, it is hard to find a study which exactly parallels the report's parameters, such as unit size, location, etc. Obviously, the few days' time available since the release of the report make it impossible to generate estimates, so we must look at a past study which fits as closely as possible and draw conclusions from it as best we can.

The arrangement of the numbers given in the report makes them difficult to compare. The "condenser and pump" are lumped together, for example, and the cooling tower or lake or spray pond is separate. We cannot determine which figure includes the interconnecting piping, or the makeup pumping system, or whether or not it was included at all.

I am elaborating on this only to show why we cannot very well say that we differ from the report by "X" percent.

Each plant is a different situation and must be looked at specifically. The costs of supposedly similar powerplants vary widely because of site peculiarities, the year of construction, and many other factors. The cooling towers will undoubtedly do the same.

Our estimates for a number of tower installations show this, so it is impossible for us to come up with a number, a dollar per kilowatt.

We can say that as best we can determine that

R. W. Patterson

the alternate cooling systems have been underestimated. In particular, the cooling pond costs do not include development of the land which very often exceeds the bare land cost, and the land costs alone are extremely modest.

Many utilities are paying much more than $1,000 per acre for land. Certainly land near the lake -- for land near the lake, this is a very low estimate except possibly for northern Wisconsin or Michigan.

The data on spray cooling canals is undoubtedly extrapolated from much smaller installations. We would like very much to have a detailed economic study prepared by the Department or a detailed review. Considerable work may have to be done to determine the interrelationship between individual sprays in a large installation (15 to 20 acres in the examples given in the report).

Dry cooling towers have never been used for a powerplant of any significant size in the United States. To our knowledge, the largest operating dry tower in the world is for a 160 MW unit. Certainly the costs for a large unit in the U.S.A. are of a speculative nature at this time.

The report appears to be self-contradictory in trying to condemn adding heat to the lake while at the same time trying to make cooling towers appear to be an acceptable alternate. In the volume on "Physical and Ecological Effects ...," page 35, it is stated that "recent findings tend to substantiate the theory that under normal conditions the principal amount of waste heat (added to the lake) is passed to the water mass, and only a relatively small proportion is dissipated directly from the plume to the atmosphere." This statement is presented to try to show that most of the heat stays in the lake. However, in the volume on "Feasibility of Alternate Means ...," page VI-26, it is stated that "when one compares the evaporation rates of wet towers and spray canals with the evaporation rate for once-through coolings (i.e., in Lake Michigan), a difference of only 10.6 minus 8.2 c.f.s., or 2.4 c.f.s. exists."

This statement is presented to try to show that cooling towers should not be penalized for water evaporation in comparison to putting the heat into the lake. It appears that two conflicting statements are used to try to win two arguments in favor of cooling towers. Logic and the laws of physics would lead one to believe that if so much water is evaporated from the lake in "once-through" cooling, most of the heat would have to be dissipated to the atmosphere.

The Department of the Interior discussion on

R. W. Patterson

blowdown from cooling towers suggests a lack of understanding of the fundamental principles of water chemistry. Blowdown is required to control scale formation caused primarily by calcium compounds in Lake Michigan water. Even with proper alkalinity and pH control, this will limit cycles of concentration to between 5 and 10. References in the text to concentrations of 100,000 p.p.m. total dissolved solids are based on the use of salt water, which has 35,000 p.p.m. total dissolved solids initially. This is mostly sodium chloride which does not form hard scales. This reference is totally irrelevant to Lake Michigan.

Because of pH control required to increase the cycles of concentrations to the 5 to 10 level, the blowdown water will have little or no alkalinity when discharged. This is contrary to the text. Also, the lack of alkalinity precludes removal of calcium and magnesium alkalinity from the blowdown as suggested in the text.

Finally, a concentration of 5 will approach the Illinois regulations for total dissolved solids, presently set at 750 p.p.m. average, assuming these wastes are undiluted with other waters. A limit of 5 concentrations appears to be the maximum based on this consideration. Such a limit would result in a large increase in water usage over that predicted in the text.

The use of Lake Michigan for cooling in comparison to the alternate cooling methods must also be evaluated in respect to land usage. Cooling towers require large areas in themselves, and must be spaced far apart to allow air to circulate through them. Figure 2 (See P. 670) shows a typical wet mechanical draft cooling tower. A 2,000 MW nuclear station would require about seven towers of this type each 420 feet long, 70 feet wide and over 50 feet high. The same station would require three of the wet natural draft type of cooling towers, 500 feet in diameter and 500 feet high. An existing site might be on the flight path of an airport, which would cause height restrictions. If the Federal Aviation Administration requested a 245 foot height restriction, for example, the natural draft cooling towers could increase in number from three to as many as ten. Dry type towers require considerably more area than wet towers.

Figure 3 (See P. 676a) shows the relationship between a dry tower and a wet tower at an installation in England. The tower on the left is a dry tower and it is our understanding it is for the same heatup load as any one of the wet towers to the right. Note not only the large size of the wet towers, but how even they are dwarfed by the dry tower.

Spray ponds or canals take significant areas (15

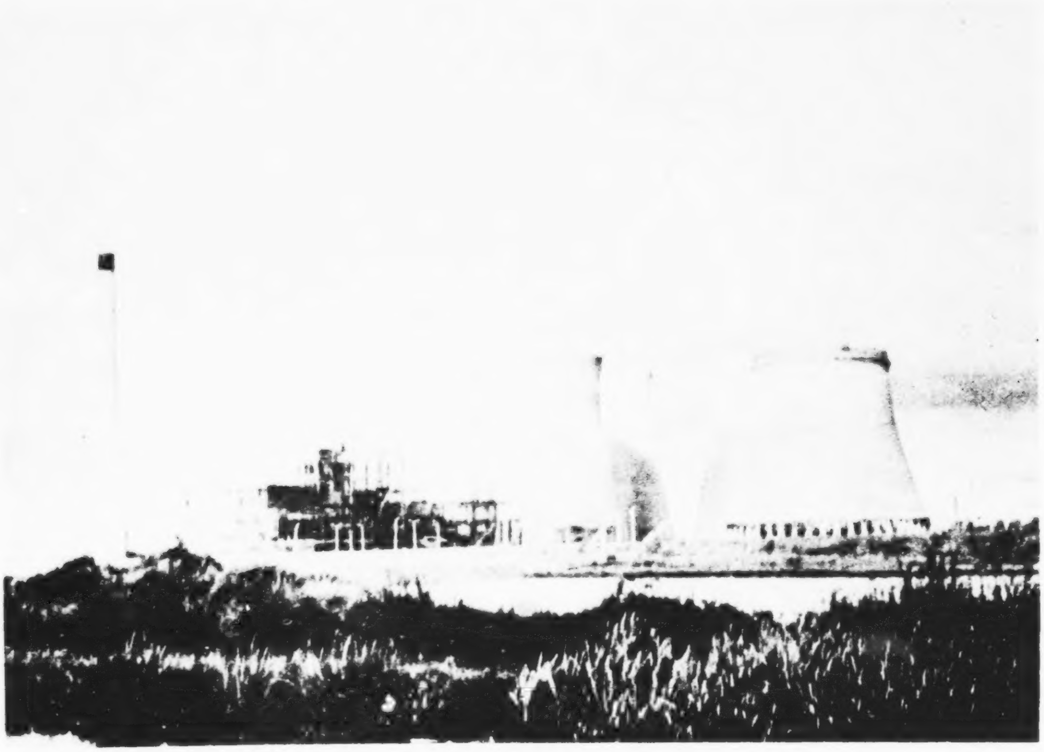


Figure 3

to 20 acres in the Interior's examples) and cooling lakes even more (1470 to 2140 acres in the examples). You may be aware of the opposition of farm groups to the use of farm land for manmade lakes. People from Illinois are aware of present opposition to a plant in this area. This opposition would undoubtedly apply also to large numbers of towers as well.

It is one thing to impose specific restrictions on powerplants at some time in the future, but quite another thing to require changes on plants now under construction.

In 1968 the Department of the Interior published a report entitled, "Water Pollution Problems of Lake Michigan and Tributaries," which stated that "assuming the powerplants to operate with an average output equal to 80 percent of plant capacity, and assuming no escape of the input heat from the water (a conservative assumption), the combined effect of existing plants plus the proposed nuclear plants, that is, (through 1973) would not raise the overall average water temperature by as much as one-tenth of a degree Fahrenheit. Even this minute increase in water temperature would be nullified during the following winter, so that no progressive warming tendency for Lake Michigan, attributable to powerplants, is expected to occur."

State regulations have also permitted temperature rises consistent with the plans for the plants now under construction. To drastically change the rules for these plants now would be unfair to the utilities who have plants already under construction and which were designed under criteria applicable at the time of commitment, and which have features not easily adaptable to the "alternate means" suggested by the Department of the Interior.

Even if the Interior Department cost estimates for alternate means of cooling were accurate, they could not be applied to plants already designed for lake cooling. When cooling towers are to be used, the powerplant equipment is designed specifically for such a system. Some of the factors which are unfavorable to the addition of cooling towers, spray ponds, etc., to plants under construction are as follows:

1. The temperature rises through the condensers of many units of Lake Michigan were limited by State criteria. As the Interior report recognizes, "cooling systems perform most effectively at elevated water temperature." Therefore, most of the present condensers are not normally considered optimum for cooling towers or ponds.

2. Dry type cooling tower installations normally employ an entirely different condenser cooling cycle philosophy. To understand the differences in the condenser cooling cycle, it is necessary to review the equipment involved. A simplified diagram of the conventional condenser cooling water system is shown in Figure 4. (P. 679)

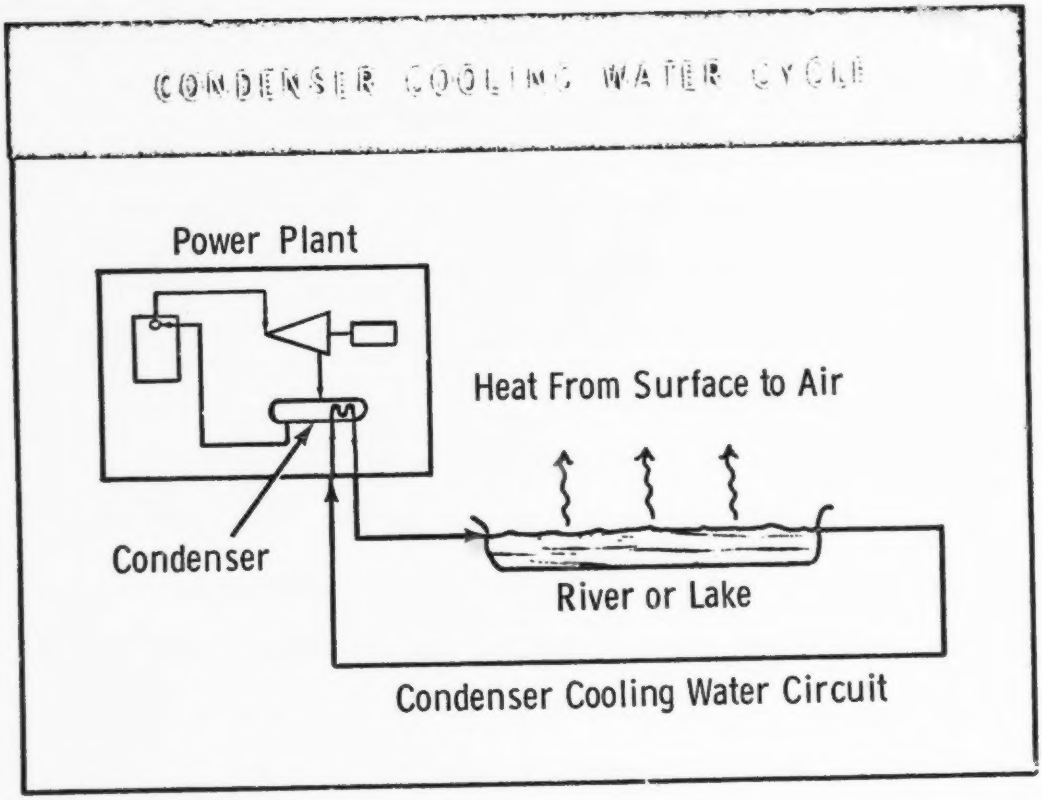
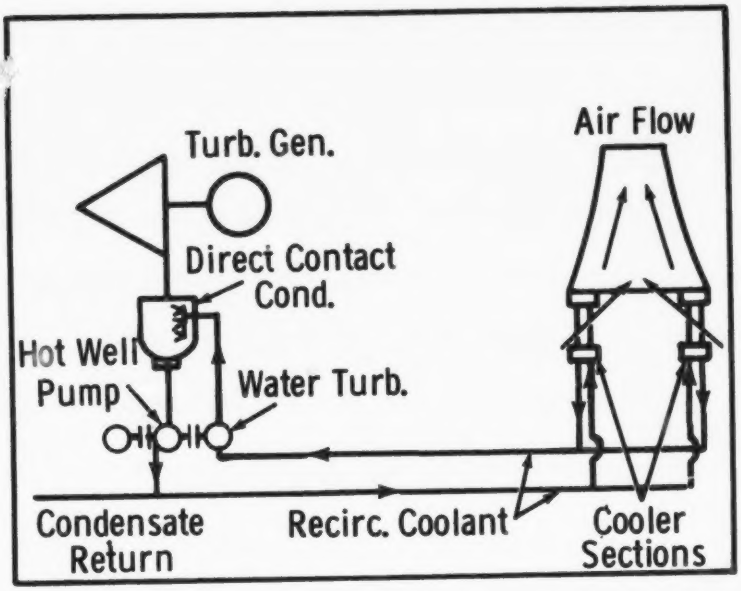

CONDENSER COOLING WATER CYCLE
Power Plant
Heat From Surface to Air
Condenser
River or Lake
Condenser Cooling Water Circuit

Figure 4

In the powerplant, steam is generated in the boiler and conveyed to the turbine where the expansion of the steam causes the rotation of the turbine and the electric generator, with the subsequent generation of electricity. The waste steam from this operation is condensed in a large condenser and returned to the boiler. In a separate system, cooling water is taken from a lake or other cooling medium and passed through the tubes of the condenser, separate from the steam, causing the steam to condense and thus absorb the waste heat from the station. This condenser cooling water is returned to the lake or other cooling medium for transmission of the waste heat to the atmosphere. It should be clearly understood that in this process the condensing cooling water only experiences a moderate increase in temperature in the range of 15 to 30 degrees and at no time is subjected to any great increase in temperature such as involved in boiling water. The nature of water in the cooling water system is not changed in any significant degree. The problem then becomes strictly one of the effect of this warm-water plume impinging upon the cooling water body.

For a system using dry type cooling towers, the optimum system does not have a tubed condenser. As shown on Figure 5 (See P. 681), the circulated water is actually part of the boiler-turbine heat cycle, and the steam leaving the turbine is condensed by intimate direct contact


Air Flow
Turb. Gen.
Direct Contact
Cond.
Hot Well
Pump
Water Turb.
Condensate
Return
Recirc. Coolant
Cooler
Sections

NATURAL DRAFT-TYPE DRY COOLING-TOWER CYCLE

Figure 5

with cooled water returned from the tower. In the dry cooling tower, heat transfer to the atmosphere is by conduction and convection through finned tube cooler sections, instead of evaporation. A tubed surface condenser designed for once-through cooling could be adapted to the wet cooling tower cycle, but only with a corresponding severe penalty in plant efficiency; however, such a surface condenser would not be suitable for the dry cycle.

3. Conventional turbine-generators operate with vacuums at their exhaust ends in the range of 1 to 3-1/2 inch Hg Abs. The manufacturers' designs are for a maximum of 5 to 5-1/2 inch Hg. The vacuum is directly related to the cooling water temperature. With a dry cooling tower system, optimum cycles operate at considerably higher pressures because the dry tower is simply unable to provide the condensing water at the cool temperatures available with wet systems. In summary, neither the condensers nor the turbine-generators for stations now under construction are compatible with dry cooling towers.

4. Plants already committed are in various stages of design and construction. The majority of these are scheduled for operation prior to the summer of 1972. Those familiar with the complexities of design and construction will realize that the facilities for withdrawing water from Lake Michigan and returning it are at an

advanced stage, and, in fact in a number of cases, completed. Many millions of dollars are already spent. But of even more concern is the time that has been spent, which cannot be regained. The time to design and construct a cooling tower system will vary considerably with each plant because each will have unique problems in trying to install cooling facilities at a plant not designed for them. But is is almost certain that any plant scheduled for operation in under 2 years cannot have cooling facilities installed prior to the operating date. Interfering with the operation of these plants would jeopardize the power planning of the utilities.

5. In previous paragraphs it has been pointed out that sites already committed cannot now be optimized for such things as drift of cooling tower fog in relationship to highways and communities, proximity to airports or flyways, and the land area that would be required for cooling towers, cooling ponds or spray ponds. For the plants under construction, there are no alternatives but to use the present locations, whether or not they are at all feasible for the installation of new cooling facilities.

In summary, we believe that for the near future at least the heat effect of powerplants on Lake Michigan are of much less consequence than implied by the Department of the Interior report.

The alternatives suggested by the Department of the Interior may impose problems for the adjacent communities and have an effect on the lake itself which cannot be overlooked. The alternatives will also cause the plants to be less efficient, and this will mean more fuel consumed and more waste heat to the total environment.

Certainly we must differentiate between the heat that would be added by plants built in the next 5 years or the next 10 years and those postulated for the next 30 years.

If plants now under construction are not permitted to be completed as presently designed, there could be a serious impact on the power supply in the Midwest.

Thank you.

MR. STEIN: Thank you, Mr. Patterson.

Any comments from the conferees?

MR. PURDY: Mr. Stein.

I am wondering if Mr. Patterson or his colleagues -- if they can take a new plant, a set of conditions in Lake Michigan that might represent summertime conditions and critical conditions that you might anticipate and which occur over a significant period of time, and then calculate under a given set of heat projection rates and Delta T, the number of acres of the lake that would be affected by various temperature extremes. Can you do this at this point in time with the present state of the art?

MR. PATTERSON: Definitely. We have been involved in a great number of cooling lakes, and have computer programs for determining the heat radiation, and so on, for optimizing the size.

MR. PURDY: Thank you.

MR. STEIN: Are there any other comments or questions?

MR. MAYO: I have one.

MR. STEIN: Mr. Mayo.

MR. MAYO: You indicate, Mr. Patterson, that the estimates prepared by the Department for the various types of auxiliary cooling systems are far below the estimates that you folks have made. How far below? Could you give us some idea?

MR. PATTERSON: Well, I tried to steer around that because there are so many variants that I would hate to come up with a number. I would be very happy to take the Department's estimates and review them to see whether there are figures which we would disagree with. We have no exact comparable estimate for a thousand megawatt fossil fuel in this area for construction in, say, the next few years. All of these things vary with time and location, and so on. We cannot say this is the number that we compare with the Department's estimates.

MR. MAYO: Your comment, then, perhaps is based upon engineering intuition?

MR. PATTERSON: No, it is based on looking at many other estimates of many other jobs and getting a feeling for what it would probably be at this size and this location, and built in, as I say, the next few years.

MR. MAYO: Would your comparison have been based essentially on a difference in capital costs as distinguished from a difference in total cost?

MR. PATTERSON: No, it would be both. The capital cost is what I was referring to basically but, as I said, I don't know whether they have taken full cognizance of the power costs, for instance, the power losses, the cost of adding capability at some other unit to make up for the power that is lost for the cooling cycle, the lower efficiency.

MR. MAYO: It is my understanding that these have been taken into account.

MR. PATTERSON: I asked this question yesterday. You cannot get the figures out of the report. That is why I say that there is a question in our minds whether they have been adequately taken care of.

MR. MAYO: I certainly hope that as the companies proceed with the evaluation of the Department's report, you will carry your evaluation out to the costs that were compared in the report, so that we don't end up with the critics trying to compare differences in capital costs, when the point that we were making a particular effort to stress was the relatively small difference in total cost to the consumer. I think this is a very interesting point. I think it is one to which the power companies should very appropriately address themselves, because this is the cost that I think is most significant to the public.

If we are talking about ranges of difference that might be in the magnitude of 20 percent in capital costs -- from 30 to 40 percent in capital costs would come out at the end in terms of total cost in the magnitude of a penny per month or two cents per month, then I think the estimates that we have made were very reasonable ones.

MR. PATTERSON: We would be happy to do this. It would be helpful if the data prepared for this report could be made available.

MR. MAYO: Well, I think you need only get in touch with Mr. Tichenor. The data is available for whatever scrutiny you want to put it to.

MR. PATTERSON: We would be happy to.

MR. MACKIE: Mr. Stein, referring to the second paragraph in the conclusions of this paper, they state: "The alternatives suggested by the Department of Interior may impose problems for the adjacent communities and have an effect on the lake itself which cannot be overlooked." What effect on the lake is it you are speaking of?

MR. PATTERSON: Evaporation perhaps. Greater evaporation to some extent, and putting the heat into the lake.

MR. STEIN: Are there any other comments or questions?

I would like to call your attention to one factor here which I think is a threat not only from your paper but a lot of the others, and that is, in some ways, the last sentence in your report. You say: "If plants now under construction are not permitted to be completed as presently designed, there could be a serious impact on the power supply in the Midwest," and you have had some considerable discussion on that with existing plants or plants under construction.

One of the trials in pollution control is that we deal in -- that is, the regulatory agencies -- challenges. Now, if you look at the problems that have been created, I don't think you have to go very far. If you go to the South Works of U. S. Steel and see what they had to do to put in the treatment facilities which would protect Lake Michigan, it was practically an urban renewal program. There was no place to put anything. You had to rip something down to put the waste treatment facility up, and they had the same problem that you have in the city with urban renewal. You have to keep the people living; you have to keep the traffic moving. And they kept production moving.

I think what U. S. Steel did not have was that if they didn't do it, possibly you could get the steel somewhere else from one of their competitors, not that you wouldn't have any steel in the Midwest.

No one disputes that the kind of pattern the power industry has is one of an exclusive franchise. If we are dealing with an industry with this pattern, such as the power industry has; if we are going to present the argument that power is not available to other industries; that if when we are dealing with an older plant even a plant that is under construction, we just may not be able to get power because we are going to protect the environment -- I think that this kind of argument coming again and again is going to need some very careful scrutiny on how we deal with this.

Do you have any comment on that?

MR. PATTERSON: I think the testimony from some of the utilities can expand on that somewhat more. I can only say that the way the power situation stands now, the units now under construction are being counted on for the next few years, that if there is an interruption, there just is no place else to go. I mean you can't buy it in Europe or Japan.

MR. STEIN: Let me pose you a question, and you don't have to answer this. This may be a rhetorical question.

Let us suppose we had these requirements on the existing plants in the East and Midwest, say, last year, and let's suppose we had the brownouts we just experienced in the past few weeks. The question is: Do you think that the regulatory agencies would have been blamed for the brownouts because of their restrictions for environmental protection? Is this what we are going to be faced with later if we put the requirement to you that every time there is an insufficient amount of power that the finger is going to be pointed at the regulatory agencies responsible for the environment, or because of it?

As I said, these are rhetorical questions. You don't have to answer them.

MR. MAYO: I have a couple of more comments, Mr. Chairman.

On page 8 and 9 and perhaps a little bit of page 10 of your report, you make quite a point of discussing the inapplicability of trying to back fit dry cooling towers to existing plants that are currently under construction or existing plants. I just wanted to make the point that I don't think there is anywhere in the Department of Interior report that the proposal is made that dry cooling towers are an economical way to back fit a facility --

MR. PATTERSON: That is correct.

MR. MAYO: -- on a plant that is already under construction. So, I would hope to make it clear that at least by inference you weren't implying that the Department was, at this point in time, suggesting back fitting in the plants under construction or those in existence with dry cooling towers.

MR. PATTERSON: No, there was no differentiation between plants under construction or future plants in the report, so I thought I had better do it myself just to make sure there was no misunderstanding.

MR. MAYO: Then you go on a little bit later to make the statement that the nature of water in cooling water systems is not changed to any significant degree and then come to the conclusion: "The problem then becomes strictly one of the effect of this warm water plume impinging upon the cooling water body."

It seems to me you made that observation essentially from an engineering viewpoint and not from a biological viewpoint.

MR. PATTERSON: That is correct.

MR. FRANGOS: Mr. Chairman, just a followup on Mr. Mayo's earlier question, and that relates to these cost figures.

Did I understand that Mr. Patterson or someone from the industry will indeed furnish the conferees with their assessment of the figures presented by Interior?

MR. PATTERSON: We would be happy to do this.

MR. FRANGOS: I think it is important and I would agree with Mr. Mayo that really we recognize no problems on getting compatibility on how you make the assessment of the cost, but I think the ranges are the figures that we are looking for.

MR. STEIN: How long would that take you, Mr. Patterson?

MR. PATTERSON: It will take a while.

MR. STEIN: I would like to get those figures. I think Mr. Frangos' thinking was that could aid the conferees in making a judgment, and I am not sure how much of a while we have before we can make that judgment.

MR. PATTERSON: Can we discuss that and get back to you before the end of the conference?

MR. STEIN: Yes.

MR. MAYO: I would like to make one final comment, Mr. Chairman.

You make the observation, Mr. Patterson, that interfering with the operation of these plants -- I think you are talking about those presently under construction and those in operation -- would jeopardize the power planning of the utilities. I have enough confidence in the capability of the electric utility industry that I think any reasonable amount of back fitting that might ultimately be required for these facilities is not going to jeopardize the power planning. I think the utility people are very, very competent in the planning area, and I don't think it would take very long for them to make the planning adjustments that would be required, if, in fact, planning would at all be significantly impacted in that regard.

MR. PATTERSON: I was referring to the plants

*Figures referred to were not supplied.

that are scheduled for the next couple of years which add up to many thousands of megawatts, and you just can't take this amount of power out of the Midwest and not have problems.

MR. PURDY: Mr. Stein.

I am not only interested in this, say, average billing per customer, but also what this might mean in the way of total cost to all of the customers in the Lake Michigan Basin here -- those served by the utilities that have plans to utilize Lake Michigan as a cooling water source.

MR. STEIN: Do you think that could be included in your report?

MR. PATTERSON: That makes it pretty long.

We have to first get the data that I asked for from the Department, and then work up a construction cost, and then it is going to take some input from a number of utilities, if that is what you want, if you want the total four-State picture.

MR. PURDY: Well, does this mean that this, on an annual basis, is, say, $1 million from the standpoint of financial resources, or is it $30 million that it may cost all of the customers on the system?

MR. PATTERSON: Oh, that can be developed.

MR. STEIN: Are there any other questions?

Off the record.

(Discussion off the record.)

MR. STEIN: Let's get back on the record.

Are there any other comments or questions? If not, thank you very much, Mr. Patterson.

Are there prints -- or negatives for those Figures 1 and 2 in your report?

MR. PATTERSON: Would slides be satisfactory?

MR. STEIN: Yes, slides would be satisfactory.

MR. PATTERSON: We can give you the slides.

MR. STEIN: Okay.

May we go on with the speakers?

MR. PETERSEN: Mr. Chairman, in asking questions of these representatives, it would be helpful in knowing, one, when full answers can be given, to know when the full data behind the Federal reports can be made available so it can be examined and factored into any conclusions which may be reached.

MR. STEIN: The full data behind the Federal report, as far as I am concerned, is available right now. Does anyone have a contrary notion?

MR. PETERSEN: Excellent.

Before concluding Consumer Power's presentation, I would note that you had two questions which pertained to legal matters, which perhaps should be best answered by counsel. One of these pertained to the legal necessity of all four Lake Michigan States have identical temperature standards for that lake. It is my legal position that identical standards are not required by Federal law. I am not here --

MR. STEIN: I don't think I said that. If I did it was in error, but I don't think I said it. They have to be compatible.

MR. PETERSEN: The second question pertains to the burden of proof on matters of pollution. We don't believe it is proper to begin with a conclusion of pollution, and the burden of proof is with the entity alleging pollution or setting standards to demonstrate that pollution. But as a matter of corporate policy, not legal requirements, Consumers Power Company has undertaken some studies to determine whether or not there will be adverse effects from these thermal discharges.

Now, as to future plants, if properly justified standards are set, the burden of proof may shift. And I am not saying this to start an argument on the matter, but I think these were legal questions raised that are more properly answered by counsel.

The next company --

MR. STEIN: Really, we have no difference here. As far as I understood your statement, Mr. Petersen, your industry feels that if the companies are going to use the water resources of Lake Michigan as cooling water in their plants, they should indicate, as a matter of corporate policy or as a legal requirement, that they are not hurting the environment by such use?

MR. PETERSEN: I don't speak for the industry, I only speak for Consumers Power Company, and as far as Consumers Power Company is concerned your statement is correct.

MR. STEIN: All right. Thank you.

MR. PETERSEN: The next utility will be Commonwealth Edison Company. Mr. Charles A. Bane of Isham, Lincoln and Beale, who is counsel for that company, will be in charge of their presentation.

MR. STEIN: I think it might expedite matters, Mr. Bane, let's talk about just the mechanics. You have a long presentation. If once you get up there, do you want to run for awhile, take a break before lunch, or how do you figure you want to handle it?

MR. BANE: Anything is agreeable to us,

Mr. Chairman. If you want to break now, why that is all right.

MR. STEIN: How long will your first presentation take?

MR. BANE: The first presentation will be about 20 minutes or a half an hour.

MR. STEIN: Why don't we take that one first and take a break after that, and then continue. We will go to lunch.

MR. BANE: Charles Bane, B-a-n-e, Isham, Lincoln and Beale.

Mr. Chairman, the Commonwealth Edison presentation will consist of the following witnesses --

MR. STEIN: May we have your full name, sir?

MR. BANE: Yes. Charles A. Bane, B-a-n-e, of the firm of Isham, Lincoln and Beale, One First National Plaza, Chicago, Illinois 60670, counsel for Commonwealth Edison Company.

The Commonwealth Edison Company's presentation will consist of the following witnesses: First, Mr. Byron Lee, Jr., Assistant to the President of the Company, who will present a policy statement on behalf of the Company.

We will then go into a number of expert

witnesses who, in the course of their testimony, will, I am sure, cover the points that were made by Mr. Stein at the beginning of today's session and a number of others that are relevant and important. The first of these expert witnesses will be Dr. Wesley O. Pipes, Professor of Civil Engineering and of Biological Sciences at Northwestern University, who will describe the study program which Commonwealth Edison Company has undertaken on Lake Michigan.

Next, Dr. Donald W. Pritchard, Director of the Chesapeake Bay Institute and Professor of Oceanography, The Johns Hopkins University, who will discuss the way heat from a cooling water discharge behaves after it is put into a lake.

Next, Dr. G. Fred Lee, Professor of Water Chemistry, University of Wisconsin, who will discuss the chemical effects resulting from the introduction of cooling water discharges into the lake.

Next, Dr. Andrew Robertson, Associate Professor of Zoology, University of Oklahoma, who will discuss the effects of the input of heat on the ecology and general biology of the lake.

Next, Dr. Edward C. Raney, Professor of Zoology at Cornell University, who will discuss the impact of cooling water discharges on fish.

Next, Dr. Wesley O. Pipes, again, for his recommendation regarding thermal discharge regulations.

Then, finally, Mr. O. D. Butler, Assistant Vice-President of Commonwealth Edison, who will discuss the alternative cooling possibilities for the Commonwealth Edison plant at Zion.

I believe that last night the copies of the proposed testimony were distributed to the conferees, with the exception of the statement of Mr. Byron Lee which has been distributed this morning.

With respect to cross examination, Mr. Chairman, we are agreeable to anything that you will or have proposed. We would suggest -- and I believe this is in line with what has gone before -- that the conferees can break into our testimony, or they can reserve until the end of the presentation by Commonwealth Edison Company -- all members of the panel. All of the witnesses will be available.

Several of them -- several of our people are having difficulty in staying over and consequently I would like to suggest -- and I think this is also perhaps a fairer way to go abbut it -- that the members of the public should also be available and should be allowed to cross-examine our witnesses at the end of our presentation rather than at the end of the entire power industry's testimony. That would be most convenient for us, and I think convenient for the public. We would expect that that termination of our testimony would take place sometime this afternoon.

MR. STEIN: We would be happy to do that.

Without objection, I think this will take most of the day.

By the way, Mr. Bane, would it be possible -- do you have another set of the papers that you gave or have you exhausted your supply?

MR. BANE: No, I am sure that we have another set.

We have given the reporter five sets, I think, altogether.

MR. STEIN: I would appreciate another one, but I think we can proceed on that basis.

If we are going to have this open to the public, they should be able to direct their questions to Commonwealth Edison and Consumers Power together. We will do them all this afternoon.

MR. BANE: I am sure that is agreeable to Consumers and EEI, although I don't speak for them.

MR. STEIN: Because otherwise, I think it will possibly get this a little out of order.

MR. BANE: Yes. As we said at the beginning -- with apologies to Chairman Currie -- this is basically the material that we have presented to the Illinois Board, so much of it will be repetitive for him. But we believe it is important for these conferees to have the material also.

We will start with Mr. Lee.

STATEMENT OF BYRON O. LEE, JR., ASSISTANT TO THE PRESIDENT, COMMONWEALTH EDISON COMPANY, CHICAGO, ILLINOIS

MR. LEE: Thank you, Mr. Bane.

Mr. Stein and conferees. Mr. Bane said my name is Byron Lee, Jr. I am Assistant to the President, Commonwealth Edison Company, and my purpose here today is to explain Commonwealth Edison's position in connection with the hearings and workshop being conducted here.

Commonwealth Edison Company has two responsibilities: 1) to provide reliable electric service to 8 million people and 2) to minimize the impact on the environment of doing so. Let me explain our views on how we can perform our responsibilities without conflicting with yours.

This body must consider to what extent and under what conditions the discharge of cooling water into Lake Michigan is compatible with protecting the lake's quality. There are some who take the position that no such discharge can be permitted without harming the lake. The Fish and Wildlife Service has recently projected thermal loads on Lake Michigan in the year 2000, assuming that powerplant technology will not change between now and then and that all powerplants on the lake will operate at 100 percent of capacity -- a completely unrealistic assumption. On this basis, the Fish and Wildlife Service has argued that the thermal load on the lake will be larger than it can support. Therefore, they argue, discharges must be stopped now.

As indicated yesterday, they have modified that slightly but the conclusions are the same.

We regard this position as unsound. The testimony we will present at this hearing shows that properly managed thermal discharge will not harm the lake. Nevertheless, maintaining the quality of the lake is too important to permit any but conservative measures. Therefore, we propose a solution which meets four tests:

1) It will avoid damage to the lake; 2) It will conserve committed resources; 3) It will help avoid air pollution and fossil fuel shortages; 4) And it will be subject to change from time to time.

Our proposal is:

1. Only plants operating or committed at Lake Michigan sites should be permitted to discharge cooling water into the lake, using properly designed discharges and subject to temperature limits such as those in the current Illinois standards.

2. Provision should be made at each such plant for careful monitoring of the discharges.

3. Powerplant cooling water discharges, in addition to those already committed, should be installed only after two conditions have been satisfied -- first, a full year's operation for each of a minimum of five large units confirms what the existing evidence indicates -- that such discharges will not adversely affect local conditions in the lake; and, second, review of the aggregate effects of actual operations has demonstrated the absence of adverse effects on the lake as a whole.

Commonwealth Edison Company, for its part, is willing to build no more units with once-through cooling on Lake Michigan until these conditions have been met.

B. O. Lee, Jr.

This proposal originates, of course, in our planning and studies for our Zion Nuclear Generating Station and I will talk about these in a moment.

It should be noted, however, that the deliberations of this body may affect not only new power generation installations on the lake shore, but also existing generating stations as well as sewage and water facilities and industrial plants, and you commented on this, Mr. Stein, several times during the first day and a half.

Edison's lake shore generating stations today have a capability of about 2 million kilowatts requiring use of cooling water. This represents 18.5 percent of Edison's present capability. Indeed, Lake Michigan today provides cooling water for 8.4 million kilowatts in Wisconsin, Illinois, Indiana, and Michigan, or about 19 percent of the capacity in these States. And, of course, there are many other industries and municipal installations around the lake which discharge heated water.

Let me now turn to our Zion Station and the conclusions we have drawn from our work there. We are building two nuclear fueled electric generating units, each with an expected capability of 1.1 million kilowatts. When the second unit is completed in 1973, Zion Station will provide about 13.5 percent of the total capability of Commonwealth Edison Company's system. We believe that the once-through cooling system designed for Zion is the best environmental solution available at that site, and that proper water quality standards should permit its operation as planned. Our reasons for this position and our recommendations as to the manner on which standards should be set will be dealt with in detail by the expert testimony which will follow my preliminary statement. Our position and the basis for it may be summarized as follows:

1. We have designed Zion with an offshore, high-velocity discharge which will protect the shore and bottom, sharply limit localized temperature effects, and minimize the period during which the entrained organisms are exposed to warm water.

2. We are carrying out the most comprehensive program of environmental studies ever conducted on an inland body of water. Even though we have complete confidence in our design, we recognize the necessity of monitoring the Zion discharge to make certain that experience bears out our prediction of no damage to the lake. These studies include consideration of both nuclear and cooling water aspects. Since these hearings are concerned primarily with lake temperature, one of our witnesses

will present a description of temperature-relevant studies for the record. The work done to date as a part of this extensive program indicates that no significant biological damage is to be expected from the Zion discharges. This is confirmed by the independent review of the scientists we have retained to examine the question.

3. A number of independent organizations are conducting similar or parallel studies to identify any adverse effects from the Zion discharge and promptly bring them to the attention of the regulatory bodies concerned. The organizations making these studies include Argonne National Laboratory, Metropolitan Sanitary District of Greater Chicago, and EPRO, the Environmental Protection Research Organization, a privately-financed conservation-motivated organization. Argonne is coordinating a full exchange of the data acquired in these studies.

4. The extensive surveillance of Lake Michigan waters resulting from our efforts and those of others will make possible a direct assessment of the effect of Zion Station by comparing water quality after the station goes into operation with water quality before operation begins. There will inevitably be prompt discovery if there is error in the forecast that Zion will not have an adverse effect on the waters of Lake Michigan.

5. The scientists whose testimony will follow mine are of the opinion that any adverse effect which this surveillance might disclose would be localized and reversible. Permitting Zion to go forward, therefore, with the discharge presently planned is not an irrevocable decision; if the discharge is shown to be harmful, it can be modified or stopped and a substitute cooling method used.

6. Permitting the Zion discharge has distinct ecological and service advantages, both short-term and long. Today, there is a nationally recognized problem of fossil fuel supply, particularly fossil fuels with low sulphur content. The two Zion units, when in service, will supply electric energy which otherwise would require over one-half million tons of coal a month. Early service dates for these units, therefore, will both help reduce the impact of the fuel shortage and avoid the emission of very substantial quantities of fossil fuel combustion by-products. Long run, so long as no harm is done to the lake, the Zion discharge as designed is preferable to cooling towers at the Zion site. While cooling towers may be a good and economic solution for generating units designed for them and located in a sparsely settled area where thorough meteorological research demonstrates they

will not adversely affect the countryside, this is not the situation at Zion. Zion was designed for once-through cooling; it is close to a congested area and an airport; it is near one of the best recreational sites in northern Illinois; and the meteorological conditions are far from ideal. The use of the present Zion design will, in the short run, avoid delays in service which could threaten the reliability of power supply because of capacity and fuel shortages. For the life of the plant, it will avoid the economic, esthetic, and meteorological disadvantages of large and unsightly cooling towers on the lake shore.

The Zion plant discharges fall well within the temperature limits of the existing Illinois regulations for Lake Michigan, assuming a reasonable mixing zone -- and our design calls for a small one. We regard the Illinois standards as sufficiently restrictive. Our experts advise us that there is no scientific evidence justifying any more stringent regulation on general temperature levels. We urge that the Illinois standards be continued in effect.

As indicated at the beginning of this statement, we are prepared to add an additional element of conservatism. Our proposal involves limiting powerplant discharges into the lake to a level below that anticipated for 1980 until a further demonstration that water quality will be preserved. We believe that there is no evidence suggesting that so restrictive a rule is necessary. This proposal would limit the level of heat discharges to less than a quarter of the level estimated for the year 2000 in the Department of the Interior Fish and Wildlife report. That estimate was the primary basis for its adverse conclusions. We suggest the restriction only so that there is complete confidence that no significant risk to the lake is involved in meeting the need for electric power.

MR. STEIN: Thank you, Mr. Lee. Are there any questions or comments from the panel?

Mr. Lee, who selected that Zion study site?

MR. LEE: Who selected the Zion site?

MR. STEIN: Yes. Your company?

MR. LEE: Yes, sir, we bought the site over 15 years ago.

MR. STEIN: And how long will it take if there is damage for you to put in an alternate method. Let's suppose you run that. In accordance with your proposal, how long would it take to put this in?

MR. LEE: Our preliminary estimates -- and Mr. Oliver Butler, our Assistant Vice-President in charge of Engineering will be on later talking about all of this --

but our preliminary reviews indicate that it would take at least 2 years and possibly 3 years to modify the plant for additional -- for some other facilities.

MR. STEIN: Sir, I fully agree with what you say. But here is the problem as I see it: You are asking that the regulatory agencies let you use Lake Michigan. If there is damage to the lake so that it is going to be 2 or 3 years before you get this fixed up and everyone in the Midwest and probably in other areas of the country because of the operation of the grid system is going to be dependent upon the Zion Plant just as a necessity for power, we are going to have a hard time cutting that back. Furthermore -- and here is, I think, the basic point -- you selected the site, as you indicated. You say that the site is close to a congested area, an airport, near one of the best recreational sites of northern Illinois. Meteorological conditions are far from ideal. This is right from your statement.

We have heard previous statements on problems of cooling towers or any kind of towers near an airport, how plumes can be bad when meteorological conditions are not just right. But the point is, as I see this, from the statement of the industry itself, you were the people who have selected the site. Then you point out that these are the problems on the site, and you say that these cooling systems are not feasible because of these problems.

I think you give us a rather difficult area to deal with, when we are faced with this situation.

MR. LEE: Well, I think we all have a difficult area to face, Mr. Stein. I think that, first -- and, of course, the siting of a plant depends to some extent upon the electrical problems -- service reliability is one of our main responsibilities.

You were talking about problems in the East -- we would like to hopefully avoid that type of thing. As a consequence, siting is an important consideration, and sites near urban areas certainly are desirable. I think that the experts that we will have on the stand following me will hopefully prove to you or at least give you very strong indications -- they have to us -- that the effects whatever they are will be extremely minimal, and that they would be reversible. It is not the problem that you espoused to, I believe, that it is not reversible. I think some of the problems you were talking about were chemical inputs and other inputs to the lake. One of our experts will talk about this, that there is a difference between that type of an input to the lake and the input of heat. I think this is one of the main thrusts of our talk -- of our expert's proposals.

MR. STEIN: Well, I don't know that we are going to have a difference there. And I said before, we have moved in several of our cases -- that is why I didn't think, as the Court proved, that we couldn't get a preliminary injunction down in Florida, because I don't think the damage is irreversible.

The issue though is when you get heat -- we know we have had areas where we have a biological desert or have had one because of the addition of heat. But not here. I want to indicate if we stop thermal discharges or we go to the winter months, we are going to get a recovery, and it is going to come back, and we are going to do this back and forth. The question is, even considering that it is not irreversible, what we are going to do to the environment. This is the point. The other point is: if you take into account these other factors I mentioned this morning, the issue may not be quite that simple. In changing the ecology of the whole area over a period of time by just taking the water out, and if you wreck the plankton and stuff, there may be real changes in the ecology of the area. But the thing that bothers me, sir, is this: On the supposition that some think more is going to have to be done at Zion, and you admit the possibility here, otherwise you wouldn't have made this proposal.

MR. LEE: No, I don't think we admit the possibility. There are certainly a great many people who doubt our conclusions, and as a consequence, as a matter of good faith, we have made this commitment.

MR. STEIN: Well, you have made the commitment. But let's suppose if this commitment is to be met, and you have to put something up that is going to take 2 or 3 years. We are going to have to put in something which is compatible to a congested area, an airport, one of the best recreational areas, and where meteorological conditions are far from ideal.

These are all the factors we are going to have to take into account, and your corporation, your company, is going to have to take into account if we are going to consider any additional facilities.

MR. LEE: That is right, and those are the same facts that we have taken into account before. I think I should hasten to add, Mr. Stein, of course, that, as you said, the Zion site was acquired many years ago. The design was started several years back. It was designed to meet the existing standards of the State of Illinois which were approved by the Department of Interior. I think that we felt -- and we still do feel -- these are good standards and there is no reason to change. As a consequence, we did not anticipate and still do not anticipate the need for supplementary cooling.

MR. STEIN: I understand your position, sir. But what I am suggesting: If there is a contrary view on the kind of cooling that is needed, once there is a commitment and Zion goes under construction or completes its operation and starts producing power, the problems we are going to have to face, if additional cooling devices are necessary, are going to be formidable indeed, given just the site description that you have given in this paper. And this is a very, very difficult determination for a body such as ours to make, because unless you are abundantly sure you won't have to make the change -- and we have all these restrictive items -- if we have to put in additional facilities later, I think you have given us quite a problem.

MR. LEE: Well, we are abundantly sure.

MR. STEIN: I know. But I think this is the crux of the issue. The question is: We know you are abundantly sure, but if the regulatory agencies agree with that point of view, and we think we are abundantly sure, we are really playing with the water quality of Lake Michigan, and some people might think that is even a little worse than Russian Roulette.

MR. LEE: Well, I hope that our experts will indicate to you that it is not quite that same kind of game.

MR. STEIN: Are there any other comments or questions?

MR. CURRIE: Mr. Chairman.

MR. MAYO: Mr. Lee, your exchange with Mr. Stein leads me to pursue a related line of thought with you. Does Commonwealth Edison have, as a matter of policy, any feeling about public involvement in pre-site selection activities of the utilities?

MR. LEE: No. I would think that we have no official position on it. This has been tried and is being tried, as you are probably aware, Mr. Mayo, in several places. At least our understanding, it has not met with the greatest of success in several instances.

I think we are -- we have a problem here, where siting is a serious problem, and it is going to certainly have to -- each individual site is going to have to be looked at separately. The sites are certainly going to have to be reviewed from their total environmental impact and this will have to be done with a great many agencies who are involved, and I think that we feel that through the Illinois Commerce Commission that they do represent a good agency to coordinate all of these reviews. They understand the need for the power, and I think certainly they understand the need for the protection of the environment.

MR. MAYO: I would make the observation, Mr. Lee, that much of the discussion this morning and yesterday certainly leads us squarely to the issue of the importance of the site to the prospects for environmental impact. I think it would be not at all inappropriate for the conferees to address themselves to this issue of site selection, maybe even to the point of making recommendations through the conference meetings through their respective States or for a much more aggressive role on the State level in the way of public review of pre-site selection consideration.

I have one or two other --

MR. LEE: I would like to add one point to that, Mr. Mayo. I think in the discussions you also have to give consideration to service reliability, as I have indicated before. This too is an important part of the siting problem.

MR. MAYO: Oh, certainly, and I think that could very well be a part of the public consideration in the pre-site selection atmosphere.

I have just one or two other questions. You made the observation that early service from the Zion Plant would reduce the impact of the fuel shortage and avoid the emission of very substantial quantities of fossil fuel combustion by-products.

As far as the Commonwealth system is concerned, do you anticipate that when the Zion Plant continues on that there would be a reduction in your fossil fuel combustion for the rest of the system?

MR. LEE: Yes, there would obviously. Of course, the nature of an electric system is that the newer units come on, the largest percentage of the time, and the older units continually decline in years, in their normal operation. And, as a consequence, we would expect that in 1973, I think, your estimates are that nuclear power would represent very close to 50 percent of our total generation in our service territory.

MR. MAYO: Would you care to make any observations on what the impact on the Commonwealth system might be if the conferees were to recommend that you suspend construction on the second unit at Zion?

MR. LEE: Yes, I would think that it would have a rather dramatic effect on our ability to serve the territory that we serve. It is 1.1 million kilowatts, as I indicated in the paper that -- both units will represent

13 and a half percent of the system capabilities, so half of that is a significant percentage of our system. I think that, of course, that would not only affect us, it would affect all of our neighbors who are here also, and we are interconnected. We think we have one of the best interconnected systems in the United States in this area, and this would have a serious effect on all of us, not only in our service territory.

MR. MAYO: Approximately how far percentage-wise has construction proceeded on the second unit?

MR. LEE: Second unit -- the construction is about 45 percent complete. The majority of the structural work is completed.

MR. STEIN: What would happen if we considered suspending you on the first unit?

MR. LEE: If we — I couldn't hear that.

MR. STEIN: What would happen if the conferees would consider neither unit?

MR. LEE: You double the problem.

MR. STEIN: We won't increase it in geometric projection, arithmetically. I feel better. But how soon — how far is your first unit along?

MR. LEE: The first unit is about 55 to 60 percent completed. We would assume that by this time next year we will be running through some of the original pre-operational tests on some of the auxiliary equipment on the unit.

MR. STEIN: And you are going ahead -- I think you indicated this -- just with that once-through cooling on both units?

MR. LEE: Yes, sir, our construction is continuing with the system.

MR. STEIN: Are there any other comments or questions?

MR. CURRIE: Yes, I have two brief comments and a question.

First of all, I have some doubt about whether the one-year test post-operation that is proposed in Mr. Lee's statement shows whether or not there will be long-term subtle effects on lake quality.

Second, I think there is some question --

MR. STEIN: Pardon. I don't want to interrupt, but I think it is fair to just ask one question at a time and see if Mr. Lee wants to comment.

MR. STEIN: Do you want to talk about that?

MR. LEE: Well, we are proposing a one-year study on five plants, which means 5 years of study. In addition, of course, we have been studying Waukegan for sometime.

It has been there for 40 years. We will continue to study it in our existing program.

There are a great many other studies -- there are other studies, I should say, on the lake -- on the plumes of various Lake Michigan plants that have been studied and will be discussed later. So I think that the beginnings of the work that has gone on and the work that we are proposing here will give us the ability to look at long-term subtle effects, Mr. Currie.

MR. CURRIE: I think one of the things I am suggesting is that five independent one-year studies of different sites might not have the same effect as a single 5-year study of one site. We are talking about long-term effects in a single place, and I just have some concern.

Secondly, I think that your proposal raises a question of fairness in the allocation of limited and valuable natural resources, namely the heat assimilative capacity of Lake Michigan. Your proposal seems to be that those who come along first should be allowed to grab all of this resource for free leaving none for anyone else who may want to build a plant in the future. I don't know the answer to the question; I just raise it.

MR. LEE: Well, I think that if I read the paper correctly, the power industry is the primary and -- if I interpret it correctly -- the only problem that is of concern as far as the Department of Interior is concerned. As a consequence, I think that this problem of others is somewhat limited, and somewhat academic maybe.

MR. STEIN: Are there any further -- yes, you had another?

MR. CURRIE: One question. On page 5 you say that the decision to go ahead with Zion without heat controls is not irreversible and that your company would be willing to accept a later requirement of back fitting on the Zion Plant should that prove necessary because of harm done by the discharge. Does that willingness extend to all existing plants, or is this a special Zion proposal?

MR. LEE: I would think that that would -- that does exist through all existing plants. The studies on Waukegan certainly are well advanced. I think that in that consideration, I think we would have to look at the life and the operation of the plant. Certainly the Waukegan plant is -- will and is declining in use, so I think that we would look at the results of the studies in that area and be guided accordingly.

MR. STEIN: Any other comments?

MR. MAYO: Yes.

MR. STEIN: Let me comment, Mr. Currie.

I think your first point, Mr. Currie, about the result of the study is well taken and I will give you a prediction now, based on many years of experience, what the conclusion is going to be at the end of the first year. The conclusion, after you hear all of these nice professionals and professors come up, will be the results are inconclusive and further study is necessary.

Mr. Mayo.

MR. MAYO: You took the words out of my mouth, Mr. Chairman.

MR. STEIN: All right.

Let us recess for 10 minutes and then we will continue. Thank you very much, Mr. Lee.

MR. BANE: Mr. Chairman, before we recess and before Mr. Lee leaves the stand, I would like to comment on two or three matters which I think have legal implications and I wouldn't want them to pass without comment.

MR. STEIN: All right.

MR. BANE: First of all, with respect to Mr. Mayo's suggestion that there is a need for aggressive State action on the location and siting of powerplants, as the witness had indicated and as I, as counsel for Edison, would like to confirm, we have a highly respectable State agency, the Illinois Commerce Commission, that administers the Illinois Public Utilities Act. Before we have authority to site a generating station, we must receive from that Illinois Commerce Commission following hearings of which notice is given to the public and at which the Attorney General, among others, is represented, we must receive a Certificate of Convenience and Necessity.

I wouldn't want any implication to be left here on the record that this site at Zion was chosen without any participation by any public officials or any pursuit of an aggressive policy on the part of the State regulatory authorities.

Secondly, with respect to the question of whether the conferees would like to recommend that the Zion No. 1 or Zion No. 2 be discontinued, I would like to state that we do not acquiesce in any position, if that is the position that you are taking, that you do have the authority to direct that we discontinue Zion No. 1 or Zion No. 2. You have some authority, but it doesn't extend that far, and I wouldn't want the witness' answers to be construed as indicating that we acquiesce that you do have that authority.

Third, I am somewhat puzzled as to what technique you are going to propose, Mr. Stein, whereby the public utilities, and particularly Commonwealth Edison, is going to have an opportunity to respond to certain statements that you make which do not partake of cross examination. But rather as your last statement or colloquy with Chairman Currie indicated, represents a conclusion that you are reaching concerning some of the issues on which you are receiving testimony.

I would like to state on behalf of our company that we would like to have an opportunity, either by brief or otherwise, to respond to those points that you make during the course of these hearings which we consider relate not to proper cross examination but to the conclusions that you ought to be arriving at.

MR. STEIN: All right. You certainly will be given this opportunity. We are not going to leave until you feel you have said anything you want to say. We will keep the record open for a reasonably short time -- a week -- to do this.

This question of whether we have the authority or not is one, of course, for the courts to decide. We are in court now on one case . I guess the issue that the case may be boiling down to is whether discharge of heated water by a powerplant is discharge which may be considered a pollutant that may be covered under the River and Harbors Act of 1899. If that is the way the industry wants these conclusions to be reached, I guess when there is a difference of opinion in our society, we have a court system that decides it.

I think your points are well taken, Mr. Bane. I have not made any conclusions as far as I am concerned, and I didn't think my remarks were made to be directed at conclusions. I am just -- as a matter of fact, I have, at this point, certainly myself a very open mind on this. We have not heard from all of the companies yet -- (Laughter) -- well, that indicates to me where our audience comes from. But there have been no conclusions reached. The conferees will reach the conclusions.

I also would like to point out, sir, that I am chairman, and the conferees arrive at the conclusions themselves, and I think they are all pretty independent-minded people.

MR. BANE: We are glad to hear that.

MR. STEIN: We will stand recessed for 10 minutes.

(Short recess.)

MR. STEIN: Let's reconvene.

Mr. Bane, if it would be agreeable, I think it might be wise it we can break -- I think we will have more flexibility if we can go to lunch -- do you think -- about 12:00 o'clock -- and then we can come back and we will have a bigger push in the afternoon -- more time to deal with this.

MR. BANE: All right, sir.

Our next witness will be Dr. Pipes, and I think he will run just about until 12:00 o'clock.

Dr. Pipes.

STATEMENT OF WESLEY O. PIPES, PROFESSOR OF CIVIL ENGINEERING AND PROFESSOR OF BIOLOGICAL SCIENCES, NORTHWESTERN UNIVERSITY, EVANSTON, ILLINOIS

DR. PIPES: Mr. Chairman, members of the conference and ladies and gentlemen.

I have a statement which has been submitted in writing. I am going to ask that the statement be made a record of this conference. In the interest of expediency, I am going to try to summarize some of the major points in the statement which I have made.

MR. STEIN: Without objection, Dr. Pipes' statement will be included in the record as if read.

(The statement above referred to follows in its entirety.)

STATEMENT ON STUDIES OF TEMPERATURE EFFECTS ON LAKE MICHIGAN

by

Wesley O. Pipes

September, 1970

Introduction

I am Wesley O. Pipes, Professor of Civil Engineering and Professor of Biological Sciences at Northwestern University. I have been on the faculty of Northwestern University for the past twelve years. During this time my primary educational effort has been teaching water chemistry and pollution biology to graduate students in sanitary engineering. I have published over thirty papers on waste treatment and water pollution. I am a member of the Technical Advisory Committee on Water Resources of the Northeastern Illinois Planning Commission and the committee which prepared the 13th edition of Standard Methods for the Examination of Water and Waste Water. My curriculum vitae is appended to this statement.

I was graduated from North Texas State University with a B.S. in Biology in 1953. I also received an M.S. in Biology from North Texas State University in 1955, and a Ph.D. in the field of Sanitary Engineering from Northwestern University in 1959.

Previous Studies

In March of 1968, I was asked by Commonwealth Edison Company to advise them in connection with a short term study of Lake Michigan in the areas of Waukegan Station and Zion Station. The purpose of this study was to establish background information on the water quality in this region and determine the nature of the aquatic communities present so that an evaluation of the possible effects of the discharges from the two stations could be made. Waukegan Station, as you may know, has a steam generating capacity of 1047 megawatts electric and at maximum capacity discharges 875,000 gallons per minute of condenser water with a temperature rise of 12°F. For this study, I worked with Dr. L.P. Beer. A series of samples was taken and analyzed during April, 1968. A report on this study was prepared and published by Commonwealth Edison Company in June, 1968. This report was presented to a number of state and federal agencies with a request for their comments and was made available to all interested parties.

The short time sampling program of April, 1968 resulted in the findings that there were very minor differences in water quality and in planktonic organisms between water samples from the Waukegan Station discharge plume and a similar area four miles to the north. These differences were well within the range of variation expected for the sampling and analytical procedures used. That is, we did not find any significant difference between the Waukegan Station discharge plume and the control area on the basis of the water and plankton samples.

We also took several grab samples of the benthic community in the area of the Waukegan Station discharge plume and the control area to the north. Samples of benthic organisms have proved to be of great value in water pollution investigations because these organisms have a strong tendency to remain in a specific location and the benthic population reflects changes in water quality over a long period of time. Plankton and fish communities respond more to water quality changes in the overall body of water than to changes in a particular area. The difficulty with using benthic organisms as indicators of pollution is that there are many causes of variation in the benthic community which are the result of natural fluctuations in ecological factors. For instance, in this region of Lake Michigan, benthic organisms are very scarce at depths less than ten feet apparently due to the mechanical abrasion of waves and currents. There are also changes in the benthic population depending upon the composition of the sediment.

We found considerable variation in the benthic organisms in the different samples which we had taken in April, 1968 as would be expected with the variation in water depth and sediment types present. However, the benthic organisms of Lake Michigan which are most indicative of good water quality, crustacea and fingernail clams, were found in reasonable numbers in the area of the Waukegan Station discharge plume. The numbers of these organisms was not greatly different between the plume area and the control area to the north.

On the basis of the April, 1968 study, it was concluded that the Waukegan Station discharge had not eliminated any planktonic or benthic organisms from that area of Lake Michigan influenced by the discharge plume. Therefore, it was inferred that the Waukegan Station discharge had not produced any gross pollutional effect. The results of this short term study also led us to recommend that a long-term monitoring program to run from two years prior to start-up of Zion Unit No. 1, to two years after start-up, be established. This program was intended to provide more detailed information on water quality and aquatic communities in this region of the Lake and for determining if any gross changes occurred as a result of the discharges from Zion Station.

In June, 1969, Commonwealth Edison Company established a program with Industrial Bio-Test Laboratories, Inc., of Northbrook, Illinois, to carry out this monitoring program. As a part of this program, samples were collected in August, October and December of 1969.

Interpretation of Temperature Effects

At this point I would like to introduce some comments on the technique of measuring pollutional effects. In my opinion, it is absolutely necessary to conduct an investigation of the environment in question in order to demonstrate pollutional effects. Laboratory studies of the tolerance ranges of aquatic organisms and calculations of permissible loadings are helpful as guidelines to determine what specific problems may or may not exist. However, there are so many factors which may have a critical influence on the manifestation of any particular pollutional effect and these factors are so variable in nature that there is always a great deal of uncertainty in any prediction of the effects of any discharge. What is required is a comparison of samples from the area influenced by the discharge and samples from a comparable area which is not influenced by the discharge.

In conducting the field investigation to determine whether or not there are any pollutional effects, it is necessary first to determine if any effects at all are to be expected in the overall receiving water body or if the effects will occur only in a limited local area. This is done in terms of primary effects and secondary effects. The primary effects are qualities of the discharge itself which are measurably different from the receiving water body. Secondary effects are changes in water quality or in aquatic communities in the receiving water body which are induced by or correlated with some primary effect.

In this particular case, the primary effect is a temperature change. The temperature change itself is not a pollutional effect unless it interferes with some beneficial use of the water or in some way damages the aquatic communities of the lake. It has been demonstrated that the primary effect, temperature increase, is measurable only within a limited distance from the point of discharge. Therefore, if a pollutional effect is to be demonstrated, it is necessary to investigate possible secondary effects. These postulated secondary effects are changes in aquatic communities such as the plankton, periphyton, benthos and fish. These changes will have to be measured in the area of the primary effect and related to water quality and aquatic populations in the entire body of water.

The measurement of the primary effect is direct and relatively easy. The measurement of secondary effects is complicated. If we were dealing with gross pollution, the secondary effects would be easily measurable at the present time as elimination or major alteration of some components of biological communities. However, we have already demonstrated that the same components of the biological communities are present in the area of measurable temperature change as in comparable control areas. We are dealing now with the possibility of subtle changes in population distributions in aquatic communities. If there are gross pollutional effects which would not be demonstrable until several years hence, they should be measurable as subtle effects now.

Because of the approach which has been taken by some other investigators, it should be emphasized here that the only practical approach to establishing whether or not any ecological effects actually occur is to measure temperature differences and changes in aquatic communities. Temperature change is a measurable quality whereas heat load is not directly measurable. The British Thermal Unit (BTU) and the calorie are hypothetical concepts which are inferred from measurable temperature changes and used to relate temperature changes in one substance to temperature changes in another substance. The response of organisms to heat is a response to temperature not a response to heat load. The relation of BTU's to effects on aquatic communities is complicated by a number of factors and there are large uncertainties in predicting these effects in a natural situation by theoretical calculations. However, given an adequate effort direct responses to temperature changes are measurable.

Water quality parameters and components of aquatic communities vary greatly due to natural causes. In order to prove that temperature changes are causing subtle secondary effects, it is necessary to determine first what the range of natural variation is and then to show that the variation in some aquatic community in the area of the temperature change is significantly different from the natural variation. This requires a great many samples for chemical and biological analysis and statistical analysis of the data obtained. Our current estimate of the numbers of samples required to demonstrate the subtle effects on a statistically significant basis is between five hundred and one thousand samples collected over a one-year period. This is the effort required to determine if any measurable secondary effects are occurring.

In order to demonstrate pollutional effects from a thermal discharge, it is necessary to undertake an extensive field investigation to compare measurable changes in water quality or aquatic communities in the area of temperature increase with natural variation in these parameters. If gross pollutional effects were present, these could be detected with only a few samples. However, gross pollutional effects as a result of condenser water discharges into Lake Michigan have not been found. We are dealing with the possibility of very subtle effects which could be obscured by natural variations. Therefore, a well planned field investigation extending over at least a year's time is required.

Present Studies

In the fall of 1969, Commonwealth Edison Company asked me to design a series of studies which would provide enough data so that subtle effects of the Waukegan Station discharge upon the aquatic communities could be measured and so that better estimates of the effects of the proposed Zion Station discharge could be made. Actually, for the type of studies which we are planning, it is necessary to have a great deal of preliminary information before the details of the study program can be specified. From January, 1970 through June, 1970, I worked with Industrial Bio-Test Laboratories, Inc. using a large number of experts on water quality and aquatic biology as consultants to develop the study plan.

In order to measure any of the possible secondary effects of a temperature increase it is necessary to know specifically what effects are being searched for and to have a well thought out plan of investigation to detect them. In a scientific investigation the effects which are being searched for are formulated in terms of questions to be answered. The questions we are trying to answer are:

1. Is the dissolved oxygen concentration in the thermal discharge plume decreased below the normal concentration in a similar control area?

2. Is there sufficient biochemical oxygen demand in Lake Michigan so that a temperature increase would cause a significant burden on the oxygen resources of the water?

3. Is there any increase in total algal growth, planktonic or periphytic, in the discharge plume?

4. Is there any change in the algal species in the discharge plume compared with species present in a similar control area?

5. Are any cold-water fish being displaced from the area of the discharge plume to the extent that their populations in the lake are threatened?

6. Is there any alteration of seasonal biological events in the area of the discharge plume?

7. Are there any fish pathogens present whose activities would be increased at increased temperature?

8. Are toxic chemicals present in concentrations great enough so that an increase in temperature would make them a threat to the aquatic communities?

9. Are any fish food organisms; e.g., zooplankton and benthos, being eliminated?

10. Is the chemical composition of the water altered by passing through the condenser of a large steam electric generating station?

This list of questions was compiled after an extensive literature survey and discussion with a number of experts. Another person could come up with a different list of questions but I believe that all of the possible adverse effects of temperature increase are covered by one question or another on the list. I also believe that when we obtain the answers to these questions, we will be in a much better position to make judgments about the speculations of possible adverse temperature effects on Lake Michigan.

The types of subtle changes in the aquatic communities which we are searching for are transitory effects. There are no residual temperature effects in the water after it equilibrates with atmospheric temperature. Thus, it is necessary to look for these changes in aquatic communities in the area of direct temperature change due to the discharge plume. If any of these effects which are presently being sought actually do occur, they would be readily reversed by natural biological processes after the thermal discharges were discontinued.

How well we answer the ten questions listed above depends upon the number of samples collected, the sampling pattern, the methodology of analysis, and the interpretation of the results obtained. We are making available a detailed description of our study plan at this time so that there can be an evaluation by the scientific community of how well we have done our job so far. I am not going to comment on the study plan at present other than to say that a great deal of effort by many people has gone into its preparation and we believe that it merits a serious attempt at scientific evaluation by others.

We are now in the middle of carrying out this study plan. Some of the results will be available in finished form in six months, but other results will not be completely interpreted and written up for another nine months. We expect to obtain answers to some of our questions in explicit form when this study plan has been completed. However, some of the questions are very difficult to answer and we expect to recommend that certain parameters of water qulaity and of the aquatic communities be monitored for several years in order to give us better information.

There are also several other agencies, including the Environmental Protection Agency of the State of Illinois, the Lake Michigan Basin Office of the Federal Water Quality Administration, the Metropolitan Sanitary District of Greater Chicago, Argonne National Laboratories and the Environmental Parameters Research Organization, studying the Waukegan Station discharge plume and the area of the Zion Station discharge. We have discussed plans and exchanged information with these agencies. I believe that it is beneficial to all concerned to have this exchange of information and ideas.

We have obtained a great many results from our efforts on Lake Michigan during 1970. Dr. Beer has prepared some of the temperature data which we have collected and will present this later

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to show what a discharge plume in Lake Michigan looks like. On the basis of preliminary reviews of the chemical and biological data as it comes in, we have not found any evidence of adverse effects from the discharge into Lake Michigan. The final conclusions from this study must await detailed analysis of the complete set of data.

Summary

1. Previous studies of the Waukegan Station discharge plume in Lake Michigan have demonstrated that there are no gross pollutional effects of this discharge.

2. Waukegan Station has a generating capacity of 1047 MWE and at maximum capacity discharges 875 thousand gallons per minute of condenser water with a temperature rise of 12°F. It is of the same order of magnitude as the largest nuclear generating units now planned for Lake Michigan.

3. At present, we have underway an intensive study which has as its objective measurement of subtle changes in water quality and aquatic communities which may be associated with temperature changes in Lake Michigan.

4. If any of the possible subtle effects of increased temperature were to occur they could be reversed by elimination or modification of the discharge.

5. Several governmental and one private agency are also carrying out studies in the Waukegan-Zion area of Lake Michigan. The existence of these parallel studies provides a convenient means of verifying results.

6. I have specific recommendations to make regarding the form of proposed regulations. I prefer, however, to make them after you have heard our remaining witnesses. Until then, so that you may know my position, let me say that, based on my own work and my review of the work of others who are participants in our study, I believe that the reasonable course to follow is to allow a moderate number of discharges from large steam electric generating stations into Lake Michigan and require that these discharges be studied. It would then be possible to make a decision on whether to eliminate these discharges or to allow more of them when further scientific information is available.

W. O. Pipes

DR. PIPES: To begin with, in the statement I refer to some studies which were made in April of 1968 by Commonwealth Edison Company at the Waukegan station generating plant. This study of April 1968 was the basis for the famous or, if you will, infamous Pipes-Beer work, which has been rather widely quoted and rather often misquoted.

In respect to comments on that study, I would like to say that I believe the data in the studies support the text of the study. I might indicate in reference to this that well over half of the pages in that particular report consist of raw data, and I believe that this data does support the text of that study, the text of that report taken as an entirety.

I believe this data does not support some conclusions which have been drawn by pulling certain statements out of the report and twisting the meaning of the statements.

Now, what the April 1968 study does say is that in respect to thermal discharges into Lake Michigan at the level we are talking about at the present time, we are not talking about pollutional effects. Gentlemen, I am well aware of what pollutional effects are and what they look like. I have pulled up bridges full of ooze which were teeming with lake eel maggots and sludgeworms. I have seen lakes which were covered with floating scum or blue-green algae. I have seen rivers in which the only fish left were carp, and carp were floating up on the surface.

Now, these types of things are entirely different than the type of thing that is occurring in Waukegan station. The Waukegan station discharge, once you get your foot in this, feels uncomfortably cold most of the time.

The data in the report, I think, do indicate that there have not been the types of qualitative changes in the biota which you do find in cases of gross pollution.

The type of thing that we are dealing with -- the type of questions that we are dealing with here are questions of very subtle ecological effects. They are very sophisticated questions, and what you need to get as an answer to these sophisticated questions is a very well thought-out-in-detail plan, and a great deal of effort over a period of some time in order to arrive at answers to these questions.

Now, the April 1968 study was a preliminary study. There were some samples which were taken in 1969 -- not a great deal more -- but these were studied in

1969 and continued because the recommendations were continued that were made in the 1968 study.

During the past 9 or 10 months, I have been working, again, under request of Commonwealth Edison Company, at developing a study plan which will allow us to arrive at answers to some of these rather sophisticated ecological questions which have been derived.

I believe that the study plan -- by the way, it is being made available at the present time; copies will be available to the members of this conference; copies will be made available to anybody who writes in asking for a copy. What we are suggesting here is that Commonwealth Edison has accepted this concept of taking the burden of proof upon itself. They asked me: How do you go about developing the answers to these questions which have been raised?

I have been working on this for a number of months, and I believe that we have an approach which, to the best I can tell, is an adequate approach. What I would like to have done with the study plan is I would like to have a good scientific evaluation. There are some very good scientific people on the staff of the Federal Water Quality Administration. I have the highest regard for the scientific capabilities of people like

Fritz Bartsch, Don Mount, Clarence Tarzwell, Dave Stephan and the rest of their staff. We would very much like to have them review the study plan which we have developed and tell us where we have made mistakes in it.

I think that the question here is: having decided that there is some proof needed, what are the best ways to go about obtaining this proof? And we have done the best that we could on developing the study plan to go after these questions, and we would very much like to have the people in the Federal Water Quality Administration and other scientists take a look at this and give us their evaluation and perhaps we can arrive at a plan which will come to some conclusions in respect to the significant questions which have been asked here.

In respect to how do you get at some of these significant questions, I would like to say that the things we are looking for are very subtle changes in population distribution in various aquatic communities. We are not looking at the matter of part of the aquatic community being wiped out.

I would also like to make the comment that in approaching an investigation like this, you have to deal in temperature changes. The organisms in the lake respond to changes in temperature. They have no method of sensing

W. O. Pipes

a B.t.u.; they have no method of sensing heat, other than the temperature change which the heat induces. And so in the approach that we are using, we cannot talk in terms of B.t.u. loadings in terms of the response of the organisms in the lake; we have to talk in terms of the amount of temperature change and the area of temperature change which these B.t.u.'s produce.

I would also like to point out that in respect to looking for the subtle types of changes in aquatic communities which we are searching for at the present time, it takes a great many samples. Mr. Currie quoted from a statement I made last week in terms of the 500 to 1,000 samples. This I would like to emphasize is an estimate. The more samples we get, the better our estimate gets as to how much we need in order to answer the question within certain quantitative limits. And so the 500 to 1,000 samples is no magic number; it just happens to be our current estimate based on the numbers of data that we have collected, and so forth.

This study is under way, has been under way for a number of months. As a matter of fact, it is something we have been developing as we go along. The more time we spend at the lake, the smarter you get about what you need to find out about what is going on out there. And we do need information on the number of samples required to establish a particular point as we go along, as we get more and more data.

I am aware of the fact that the types of comments that have been made so far are not much help to you gentlemen in your deliberations as to what should be the temperature standards established for Lake Michigan at the present time. And I am in agreement with Mr. Stein with the fact that very often these studies come out with a conclusion that the data collector was not adequate or the study was inconclusive or something like that. I hope that we can do a lot better on this study than has been done on some of these studies in the past.

In the meantime and as an interim suggestion, I would like to say I believe the evidence indicates that the mixing zones which have been studied in Lake Michigan so far are not producing any pollutional effects, that this evidence should be recognized and that a limited number of mixing zones should be allowed until such time as we have the data upon which we can give you better information which can be related to standards.

Thank you.

MR. STEIN: Thank you, Mr. Pipes, or Professor Pipes, I should say.

I say this just as a general proposition. In terms of the people you are talking about I would suggest that if you are going to do these things, it might be advisable for you to get in touch with them and work up something, in conjunction with the people not only on our staff but on the State staffs, so at least we all have the same methodology that we can agree on. I appreciate your statement very much, but just a little while ago, I guess Mr. Bane called one of my predictions a conclusion. I didn't think it was a conclusion. But, Dr. Pipes from Northwestern University, the first man up, -- I never expected a confirmation so fast -- he says on page 8 -- by the way, I am not attempting to deprecate these at all -- "Therefore, a well planned field investigation extending over at least a year's time is required."

Then he goes into details on another study and says, "We expect to obtain answers to some of our questions in explicit form when this study plan has been completed. However, some of the questions are very difficult to answer and we expect to recommend that certain parameters of water quality and of the aquatic communities be monitored for several years in order to give us better information."

Again, sir, I am not criticizing this

approach one bit, but I thought it was a fairly safe prediction.

Are there any other comments or questions?

DR. PIPES: Mr. Stein, if I could answer that. The easy questions to answer are in terms of large effects. The questions which are difficult to answer are looking in smaller and smaller effects.

MR. STEIN: I recognize this. But, sir -- and I put this out because this is the issue we are going to have to face -- if we really have questions about smaller and smaller effects and these effects are considered to be significant, the question that any regulatory agency responsible for water quality has to face is whether it is going to be prudently cautious until you resolve those questions. Should the agency not permit an entry or a change in water quality, whether it is a material or diminishment of flow, an increase, or what-have-you? Or should it instead permit this activity to go on and check these subtle effects with the notion that you correct the damage once found.

Now, I think this is precisely the area in which the regulatory agencies find themselves, and we are going to have to work our way through that.

I hope that we will, with the aid of the industry, be able to come up with an agreed-upon approach to this.

Now, again -- on thinking about this in the recess -- I think we have had the same problem with regulatory agencies and industries that we see reflected here. Sometimes when we first begin dealing with a particular industry, as we are doing here, en masse, we are experiencing the same kind of situation we did with the other major industries in the country. That is, very often you may be surprised and often dismayed at the difference in philosophical or legal approach from a regulatory man in the environmental field and an industrial view. However, I have always felt that while these philosophical and legal differences still remain between us and the representatives of the other industries that we have dealt with through the years, we have always under the American system of government been able to arrive at an accommodation and a settlement and an approach to each individual case. I am very hopeful that we can do that here.

DR. PIPES: Mr. Stein, a point you raised earlier -- I think it brings out the critical issue of the biological reversibility of these ecological effects, which are still a matter of question.

Mr. Currie quite properly asked me the question last week if we had any data bearing on the biological reversibility. In the 2 or 3 days since then, we have been scratching around. We hope to prepare this data for presentation at the Illinois hearing in November.

There is some evidence in terms of the movement of organisms in the lake,from one part of the lake to another part of the lake, in response to temperature change. There is some evidence in investigations on other environments about the recovery of the environment after damage was done on the ecology of the environment. There is some evidence in the literature, particularly in the paleolimnology, when you look at sediment forms on the bottom of the lake and how the population of the lake has changed over periods of many years, and I believe that this is a pretty good record and I hope we will be able to present this a month from now.

MR. STEIN: Fine.

Are there any other comments or questions?

Mr. Purdy.

MR. PURDY: Yes. In the conclusions, Mr. Pipes, you make an -- or you reach the conclusion that the Waukegan discharge does not have gross pollutional effects.

DR. PIPES: Correct.

MR. PURDY: And certainly we need to be looking at something far less than that. I believe back in your papers you seem to indicate that it is your conclusion that the changes which you expect to find there will be no greater than those that you would expect to find under natural -- caused by natural variations. Is this correct?

DR. PIPES: Well, I didn't intend to convey that impression. I think the first point: I would like to say that as a scientist I am obligated to try to keep my mind as open as possible for analyzing data, seeing what the data looks like after it comes out.

In the second place, the point I was trying to make is that there are rather wide ranges of natural variations. Actually the temperature changes that we are looking -- outside of a similar area -- for are well within the natural temperature variations of the system that we are looking at. And due to these natural variations, it does take a great many samples, a lot of work and analysis, and a pretty detailed statistical analysis of the data we get to show the differences between the natural variations and those which might be considered as temperature changes by the discharge zones.

MR. PURDY: In Michigan -- I think it is no different than the feeling of all of the people on this board -- in Michigan, if we reasonably anticipate some adverse effects, that we need to take some action now before the adverse effects take place, and I am looking for some information from the scientific community to indicate where we can reasonably expect some adverse effects or if the scientific community believes that the likelihood of adverse effects would be very slight.

DR. PIPES: Well, the question I would ask: In your reading of an official Wildlife Service "white paper," do you find anyplace in there that they say there aren't any pollutional effects of the present discharges, or do you find anywhere in there that they say there are any pollutional effects of the discharges which are expected from plants in development in the next 5 years?

In my reading, I did not find any allegations that there were pollutional effects or that there would be pollutional effects. In my reading of the paper they were talking about very long-range effects, and I am essentially agreeing with you. It is a very difficult question to find good advice on.

MR. STEIN: Mr. Frangos, any other comments or questions? If not, I think we are a little bit ahead of schedule, and let's try to keep on this. Let's recess for lunch and we will start again at 20 after 1:00.

(Noon recess.)

AFTERNOON SESSION

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MR. STEIN: Let's reconvene.

Mr. Bane?

MR. FELDMAN: William McNamara.

STATEMENT OF WILLIAM A. McNAMARA, VICE PRESIDENT, MADISON GAS AND ELECTRIC COMPANY, MADISON, WISCONSIN

MR. McNAMARA: Mr. Chairman and members of the panel, my name is William McNamara. I am vice president of Madison Gas and Electric Company, and inasmuch as it is apparent that you will not complete the meeting today as far as all of the utilities putting in their statements, I am asking permission that our company be permitted to leave our statement in writing here with the reporter and with members of the panel, and inasmuch as -- I request that because I have been requested to be back in Madison tomorrow.

MR. STEIN: Without objection, this will be done.

(The document above referred to follows in its entirety.)

Statement of
Madison Gas and Electric Company

My name is William A. McNamara. I am Vice President of Madison Gas and Electric Company, an investor-owned public utility serving gas and electricity to approximately 76,000 customers in Madison, Wisconsin, and surrounding areas. We are pleased to participate in this workshop and to present our views on the optimum uses of Lake Michigan water.

We do not presently have any generating facilities on Lake Michigan. We are, however, partners with Wisconsin Public Service Corporation and Wisconsin Power and Light Company in a 527 MW nuclear generating plant now under construction at Kewaunee, Wisconsin on the western shore of Lake Michigan. Wisconsin Public Service Corporation, which will be in operational control of the plant, has already described the facility and our proposed use of Lake Michigan for cooling purposes. We fully subscribe to Wisconsin Public Service Corporation's statement previously made in this proceeding.

As a public utility, our primary concern is to comply with the obligation imposed on us by Wisconsin law that we be prepared to satisfy the electrical requirements of our customers. We attempt to discharge that essential service in a manner most beneficial to our customers and community. This entails consideration of a great number of factors, including the environment in which our facilities and customers exist. For over 30 years--long before the popular advent of ecology, pollution and environment--we have been dedicated to a program of minimizing the effect of our operations upon the air, land and water of our environment.

In our opinion, the selection of one technique over another for purposes of cooling, or anything else, must be made in the perspective of the total environment. Judgments based only upon the possible effect on one isolated segment of that environment are unrealistic because they ignore the close interrelation between all components of the total environment. Similarly, favoring certain water uses to the exclusion of others should not be undertaken without a full consideration of the relative importance of the uses and the long-term effect upon the whole environment. Fishing, boating and swimming are splendid forms of recreational lake usage and, as such, are important; but let us not forget that, on a per capita basis, very few people in fact elect to so utilize our water resources. On the other hand, virtually everyone benefits from judicious use of lakes and rivers in the electric generating process. I am referring not only to cost and availability of energy but also to many other more subtle benefits, such as aesthetics and the availability of land for other productive uses. Man-made cooling ponds, for example, completely change the environment of the inundated area and remove it from other productive uses. We do not, for a moment, mean to infer that artificial cooling ponds should be discarded as a cooling technique. Obviously they should not. In the right place and under appropriate circumstances, cooling ponds may well be the most attractive of the known alternatives. The same can be said about cooling towers; they are huge man-made structures and have their own environmental disadvantages.

Each situation presents its own unique problems which can best be solved only by having a variety of alternatives available. Armed with flexible tools, we can chart a course which will ruffle the feathers of environment the least. Unfortunately, the converse is also true. At the present time and given the present state of technology, we, as a public utility, would be severely hampered in our efforts to solve the waste heat problem if we lost Lake Michigan as an alternative to be considered through the adoption of thermal standards which would, for all practical purposes, preclude the use of it.

MR. FELDMAN: Do I understand, Mr. Chairman, that this permission is available for the other companies that can not stay on?

MR. STEIN: We will deal with each company as they come up and this is available to you.

MR. FELDMAN: Thank you.

MR. STEIN: Thank you.

MR. FELDMAN: Mr. Stein, I am afraid Mr. Bane got caught in a long lunch hour, but we are ready to resume on the next person who will appear at the request of Commonwealth Edison, who is Dr. Donald W. Pritchard. His testimony, as Mr. Bane indicated this morning, forms the basis for the testimony of the three witnesses who will follow him who deal with the ecology.

MR. STEIN: Would you care to give us your name?

MR. FELDMAN: I gave it to you yesterday, Mr. Chairman. My name is David Feldman from Isham, Lincoln and Beale. I am here on behalf of the --

MR. STEIN: Well, let the record show that the Chairman was here on time.

You may proceed.

MR. FELDMAN: Mr. Chairman, the next witness is Dr. Pritchard.

DR. PRITCHARD: Thank you.

STATEMENT OF DONALD W. PRITCHARD,
PROFESSOR, THE JOHNS HOPKINS
UNIVERSITY, BALTIMORE, MARYLAND

DR. PRITCHARD: Mr. Chairman, you have before you, I believe, my written statement as submitted to you among the papers that were given you by the Commonwealth Edison Company.

Since I will from time to time depart slightly from this prepared text, I would ask that the statement as written and as in your hand be considered a part of the record.

MR. STEIN: Without objection, this statement will be entered into the record as if read.

(The document above referred to follows in its entirety.)

Statement on Temperature Standards for Lake Michigan

Prepared by D. W. Pritchard

Introduction

My name is Donald W. Pritchard. I am Director of the Chesapeake Bay Institute and also Professor of Oceanography, Department of Earth and Planetary Sciences, The Johns Hopkins University. I hold a B.S. degree in Meteorology and M.S. and Ph.D. degrees in Oceanography. For the past 23 years I have conducted and directed research programs concerned with the movement and mixing of waters in lakes, estuaries, and marine coastal areas, and with the chemistry and biology of these water bodies. Investigations of the heat budget have been a part of my studies of the physical processes in natural water bodies and for the last five years I have concentrated on studies of the fate of excess heat discharged with the condenser cooling water flow from steam-electric generating plants. I have served as an advisor to federal, state and local government agencies concerning the fate of waste materials discharged into natural water bodies, and as a consultant to industry. In recent years, much of my consulting activities have been carried out as a partner in the firm of Pritchard - Carpenter, Consultants.

I have been concerned with the conservation and management of our natural resources for over 20 years. I was a member of the Board of Natural Resources of the State of Maryland for 12 years, and also served as Vice-Chairman of that Board. I am presently serving the State of Maryland as a member of the Board of Review, Department of Natural Resources; as a member of the Air Quality Advisory Board, State Health Department; and as a member of the Radiation Control Advisory Board. I have been a member of the Committee on Oceanography, National Academy of Sciences for the past 12 years, serving for some six years as Chairman of the Panel on Radioactivity in the Marine Environment of that Committee. I was also Co-Chairman of the National Academy of Sciences - National Academy of Engineering Joint Workshop on Coastal Waste Management.

A curriculum vita is attached to this statement as an appendix.

I was invited to present this statement by the Commonwealth Edison Company, Chicago, Illinois. However, the opinions and conclusions I present here are my own, and do not necessarily represent the views of either The Johns Hopkins University or the Commonwealth Edison Company.

Lake Michigan as a Receiver of Condenser Cooling Water Discharge: A Natural Resource which can be Used Without Detrimental Effects on Other Uses of the Lake.

A major purpose of my presentation here is to emphasize that Lake Michigan represents a great natural resource for cooling of water used in the generation of power, and that this resource can be used, with proper design of intake and discharge structures, without detrimental effects on other uses of the Lake, or on the natural biota of the Lake. From the standpoint of the heat carried with the condenser cooling water discharge, Lake Michigan may be considered as a temporary receiver, since, independent of the method of introduction into the Lake, virtually all of the heat rejected from steam-electric power plants will be lost from the Lake surface to the atmosphere. There is thus no permanent storage of the rejected heat in the Lake; the excess heat resident in the Lake at any given time is in transit, with the atmosphere as the ultimate destination.

Temperature standards should be set to provide both for the protection of aquatic biota and for effective use of the resource of the Lake as a heat transfer mechanism. Overly stringent temperature standards beyond those necessary for protection of the aquatic biota represent a waste of a natural resource. From the standpoint of the total economy, funds expended (that is, wasted) in meeting unrealistic standards will not be available, in the long run, to serve in meeting other important environmental protection needs; for example, in the construction of adequate muncipal waste treatment plants.

In addition to the seasonal variations in temperature, water bodies such as Lake Michigan are subject to natural variations in temperature associated with longer term climatic fluctuations. Studies of other natural water bodies of comparable size in mid-latitudes have revealed that the annual mean temperature of the surface layers show a year-to-year variation, compared to a mean over the last 50 years, having a range of nearly 7°F. Further, the mean temperature of the surface layers over periods as long as 10 years may vary from the long term (50 year) mean by 1.5°F. Spacial variations in temperature of several degrees Fahrenheit over distances of one or two miles are also characteristic of such natural water bodies. The natural biota will be conditioned to these natural fluctuations, and it is unlikely that man-induced temperature changes over any significant fraction of the Lake surface which fall within these natural fluctuations will have any measurable effect on the ecology of the Lake.

The quantitative expression giving the rate of change of heat content of a body of water such as Lake Michigan in terms of the difference between the radiation terms which add heat to the surface of the water body and the radiation terms which remove heat from the surface of the water body is called the heat budget of the Lake. An examination of the various terms which enter the heat budget for Lake Michigan can serve as a basis for a consideration of the relative significance of the heat which might be discharged into the surface waters of the Lake as a result of electric power generation. The heat budget states that the time rate of change in the amount of heat stored in the waters of the Lake equals the rate of input of solar radiation to the surface of the Lake, plus the rate of input of long wave radiation from the atmosphere to the Lake surface, minus the long wave radiation emitted from the Lake surface to the atmosphere, minus the heat loss from the Lake surface to the atmosphere due to evaporation, minus the heat loss from the Lake Surface to the atmosphere due to conduction. Since the heat concentration per unit volume is directly proportional to the temperature, the heat budget is also a statement of the time rate of change of temperature. Each of the radiation and heat exchange terms which enter the heat budget is individually much larger in magnitude than the algebraic sum of all of the terms at any given time. Thus the time changes in temperature in the surface waters of the Lake, such as the diurnal or seasonal variations, result from a relatively small difference between several relatively large radiation terms in the heat budget. Since each of the terms in the heat budget vary in both space and time, natural variations in the temperature in the surface layers of the Lake are to be expected.

Characteristic values of long term averages of the terms in the heat budget for Lake Michigan are listed below, in units of BTU/hr gained or lost at the water surface. Note that these terms are given for the total Lake surface area.

Input of solar radiation to the Lake surface	= 3.75×10^{13} BTU/hr.
Input of long wave radiation from the atmosphere to the Lake surface	= 7.50×10^{13} BTU/hr.
Loss of heat from the water surface due to back radiation	= 9.38×10^{13} BTU/hr.
Loss of heat from the water surface due to evaporation	= 1.56×10^{13} BTU/hr.
Loss of heat from the water surface due to conduction	= 3.12×10^{12} BTU/hr.

Thus, on the average, solar radiation and long wave radiation from the atmosphere provide a heat input to the surface of Lake Michigan of some 11.25×10^{13} BTU/hr; while the processes of back radiation, evaporation, and conduction of sensible heat produce a rate of loss of heat from the Lake surface totaling about 11.25×10^{13} BTU/hr. By way of comparison, the rate of rejection of heat at the condensers of a 1000 MWE nuclear power station, or a 1700 MWE fossil fueled power station, at existing efficiencies, is 6.8×10^9 BTU/hr, or six-one thousands of one per cent of the average rate of heat input to the surface layers of the Lake due to solar radiation and atmospheric radiation.

As I will demonstrate later in this statement, the most effective way that Lake Michigan can be used as a receiver of waste heat is through a combination of efficient dilution, that is mixing, of the heated effluent with the surface layers of the Lake, plus loss of excess heat to the atmosphere through surface cooling. To demonstrate the potential capacity of Lake Michigan to receive condenser cooling water discharges, I have computed the mean temperature rise of the surface layers of the Lake which would result from the discharge of the condenser cooling water flow from an unspecified number of power plants distributed around the lake shore, having a given total rate of heat rejection at the condensers of these plants, and producing a given total net electric power. This illustrative computation is made assuming "perfect" mixing of the discharged excess heat into the surface layers of the Lake, and subsequent excess heat balance due to surface cooling and advective discharge from the Lake. Admittedly, the assumption of "perfect" mixing of the heated effluent into the surface layers of the Lake is unrealistic. Departures from this ideal assumption for actual discharges of heated effluent would result in local areas having excess temperatures exceeding those calculated in this illustrative example, and also large areas of the Lake having excess temperatures less than those calculated here. Later in this statement I will give examples of the local distribution of excess temperature in the thermal plume which would result from specified design criteria for the discharge structures of a power plant.

I have used the expression "excess temperature", and it would be well to clearly state what I mean by this expression. Designating the natural, or ambient, temperature which would occur at a given location in the surface layers of the Lake, at a given time, under conditions of no discharge of heated effluent, by T_n, and designating the temperature which would occur at that same location and time under conditions of discharge of heated effluent by T_h, then the excess temperature, θ (Greek letter Theta) is given by the difference between T_h and T_n. That is, $\theta = T_h - T_n$.

The necessary input data for this illustrative computation are: (1) the surface area of the Lake, which I have taken from available publications to be 14.33 million acres; (2) the average annual volume rate of outflow from the Lake, which I have taken from available publications to be 39,000 ft^3/ sec; (3) the surface cooling coefficient for the Lake, which I have taken here to equal ~~161~~ 135* BTU/ft^2/ (°F)/ day, a value corresponding to a wind speed of 10 mph, an ambient temperature of 70°F, and an excess temperature between zero and 1.0°F; and (4) the relationship between net electric power production and the rate of rejection of excess heat at the condensers. In this illustrative computation I have used two values for this latter relationship; that is, I have assumed efficiencies now possible for nuclear power production (6.8×10^6 BTU/hr rejected heat per MWE produced power); and efficiencies now realized in fossil fueled power plants (4.0×10^6 BTU/hr rejected heat per MWE produced power).

The following table gives the results of this computation, in terms of the total rate of rejected excess heat and the total net electric power production from an unspecified number of power plants distributed around the shoreline of the Lake, for the stated values of mean excess temperature in the surface layers.

Mean Excess Temperature θ, °F	Total Rate of Rejection of Excess Heat, in BTU/hr	Total Net Electric Power Production, in MWE	
		Nuclear	Fossil Fueled
0.05	1.75×10^{11}	25,750	43,750
0.10	3.50×10^{11}	51,500	87,500
0.50	1.75×10^{12}	257,500	437,500
1.00	3.50×10^{12}	515,000	875,000

From this table it is clear that Lake Michigan has the capacity, under ideal conditions of mixing, to receive the excess heat rejected during the production of relatively large amounts of electric power, with only very small increases in the mean temperature of the surface layers of the Lake.

It should again be emphasized that the assumption of perfect mixing of the heated effluent into the surface layers of the Lake cannot be realized in the actual environment. Departures from this idealized situation for actual discharges of condenser cooling water would result in localizing any temperature increases above ambient. Thus, this example computation demonstrates that the temperature rise in the surface layers of the Lake as a whole, resulting from the discharge into these waters of the condenser cooling water flow from a total net electric power production exceeding any reasonable projection of power requirements in the foreseeable future, would be sufficiently small so as to have no detrimental effects on other uses of the Lake, or on the natural biota of the Lake. Any possible detrimental effect of the discharge of heated effluent into the surface layers of the Lake must therefore be of a local nature, occurring only in the vicinity of the point of discharge.

It is therefore desirable to examine the character of the local disturbance of the natural temperature regime resulting from the discharge of waste heat into the surface waters of Lake Michigan, for several different sets of design criteria for the discharge structure.

Distribution of Excess Temperature in the Thermal Plume From a Steam-Electric Power Plant Rejecting 6.8 x 10^9 BTU/hr of Excess Heat to the Surface Layers of Lake Michigan, Corresponding to a Nominal 1000 MWE Nuclear Power Plant or to a 1700 MWE Fossil Fueled Power Plant.

The distribution of excess temperature in the thermal plume resulting from the discharge of condenser cooling water from a steam-electric generating plant depends upon three processes. These are: (1) dilution due to momentum entrainment of cooler receiving water into the dispersing thermal plume; (2) dilution due to natural mixing processes, or turbulent diffusion, of the heated effluent into the cooler receiving waters; and (3) transfer of excess heat from the water to the atmosphere across the air-water interface due to surface cooling.

Observations of the temperature distribution in thermal plumes resulting from the horizontal discharge of heated effluent into the surface waters of Lake Michigan as well as other similar water bodies reveal that the excess heat is primarily confined to a surface layer 10 to 15 feet in vertical thickness. The actual depth to which measurable increases in water temperature above ambient may be observed depends upon the depth of the water at the point of discharge, critical design features of the discharge orifice, the slope of the bottom offshore from the point of discharge, and the natural vertical gradient in the ambient temperature field. However, experience has shown that the probable distribution of excess temperature in a thermal plume within the surface layers of Lake Michigan resulting from the horizontal discharge of a heated effluent may be computed with reasonable confidence using a prediction model in which it is assumed that the excess heat discharged with the condenser cooling water flow is confined within a dispersing thermal plume extending from the surface to a depth of approximately 10 feet. Vertical entrainment of dilution water into the thermal plume is included in the prediction model only when the design of the discharge orifice is such that the initial vertical dimension of the discharged jet is less than 10 feet.

The excess temperatures computed using this numerical predicting model apply to the water surface. It is also assumed that there is no vertical variation in temperature in the upper 10 feet. As pointed out above, actual observations in thermal plumes in Lake Michigan show that the excess temperature is a maximum at the surface, and decreases with depth. Measurements made in the thermal plume adjacent to the Waukegan Power Station show that a thermal plume at a depth of 10 feet is significantly smaller than at the surface, and that the temperatures at a depth of 15 feet are not measurably larger than the ambient temperature. Thus the areas contained within specified isotherms of excess temperatures as computed from the numerical prediction model used here are larger than would actually occur for all sub-surface depths.

Field studies of actual thermal plumes, as well as laboratory studies involving the horizontal discharge of a heated jet into a water flume reveal that within the constraints of practical design for the large majority of real or potentially real situations, the primary mechanism producing the initial decrease in excess temperature is dilution of the thermal plume by horizontal momentum entrainment of the cooler receiving waters. Dilution by the natural mixing processes becomes important only after the initial mechanical dilution of the thermal plume by momentum entrainment has altered the transverse temperature distribution from a nearly flat-topped structure to a sharply bell-shaped structure. Existing evidence indicates that natural turbulent diffusion becomes a dominant process in controlling the distribution of excess temperature in the thermal plume after the plume has been diluted by momentum entrainment by a factor of about five-fold.

The rate at which excess heat is lost from the water to the atmosphere per unit surface area is directly proportional to the excess temperature at the surface. The proportionality factor relating the excess temperature to the rate of loss of excess heat per unit surface area is called the surface cooling coefficient. Its value depends primarily upon the wind velocity, secondarily on the ambient temperature, and to a lesser extent on the actual excess temperature. For practical purposes, within the normal range of excess temperatures, the dependence of the surface cooling coefficient on the excess temperature may usually be neglected. This coefficient has the units of heat flux through a unit surface area per unit of excess temperature per unit of time; for example, in $BTU/ft^2/(°F)/hr$. The surface cooling coefficient increases with increasing wind speed, with increasing ambient temperature, and with increasing excess temperature, with the dependence on wind speed being the most important.

The fact that the rate of loss of excess heat from the water to the atmosphere per unit area of water surface is greater the larger the excess temperature,has led to the rather widely held opinion that the most effective way to use a natural body of water as a receiver of waste heat is to introduce the heated effluent into the surface layers of the water body in a manner designed to prohibit, or at least minimize, dilution of the heated effluent by the cooler receiving waters. The rate of loss of excess heat from areas having relatively high excess temperatures would thus be maximized, and the area of the lake surface within which measurable temperature rises would occur would be minimized.

An alternate hypothesis is that the most effective way to use a natural water body such as Lake Michigan as a receiver of waste heat is to design the discharge structure for the introduction of the heated effluent into the surface layers of the Lake in such a way that dilution of the thermal plume by momentum entrainment and natural turbulent diffusion is maximized. In this scheme the dilution capacity of the receiving waters of the Lake adjacent to the point of discharge of the heated effluent is used to the maximum extent practically possible. The excess temperature in the thermal plume is thus reduced rapidly by dilution. Heat loss to the atmosphere occurs for the most part from relatively large areas of very small excess temperature.

Both laboratory studies of heated jets discharged into a flowing water flume, and field studies of thermal plumes in natural water bodies, reveal that when a heated effluent is discharged at the shoreline into a transverse, longshore ambient current, the thermal plume is bent in a downcurrent direction to become parallel to the shoreline. Consequently, the supply of low temperature dilution water is cut off on the inshore side of the thermal plume, and the rate of dilution of the plume is significantly reduced as compared to the case of discharge into the receiving body of water in the absence of an ambient longshore current. If, however, the discharge is made from a structure located sufficiently far offshore, and the discharge pipelines are buried below the bottom of the waterway between the shoreline and the point of discharge, free flow of dilution water on the inshore side of the thermal plume occurs even in the presence of an ambient longshore current. Consequently, the rate of dilution in the bent jet discharged offshore approaches that which occurs in a thermal plume discharged into a water body having no longshore currents.

The following four example computations serve to provide a comparison between the distributions of excess temperature in the thermal plumes resulting from the discharge of condenser cooling water via discharge structures designed either to minimize dilution of the heated effluent or to promote such dilution. In each of the four cases described below it is assumed that a steam-electric generating plant rejecting 6.8 x 10^9 BTU/hr of excess heat at the condenser discharges the heated condenser cooling water into the surface layers of Lake Michigan. This rate of heat rejection corresponds to a nominal 1000 MWE nuclear power plant or to a nominal 1700 MWE fossil fuel power plant, at present efficiency levels. It is further assumed that the temperature rise of the condenser cooling water flow at the condensers is 20°F, and hence the required volume rate of flow of condenser cooling water is 1520 ft^3/sec. In all cases it is also assumed that the heated effluent is discharged into a waterway having no longshore currents, or that the discharge structure is located far enough offshore so that free passage of dilution water can occur on the inshore side of the bent thermal plume even in the presence of a longshore current.

Case I: Discharge structure designed so that no dilution (mixing) of the heated effluent with the receiving waters of the Lake occurs. Hence the decrease in excess temperature occurs as a result of surface cooling only. It should be recognized that it is in fact impossible to discharge the condenser cooling water flow into the Lake without some mixing between the heated effluent and the cooler receiving waters. However, it is of some interest to consider this case for purpose of comparison.

Case II: Discharge structure designed to minimize dilution of the heated effluent by the cooler receiving waters of the Lake. Dilution of the thermal plume by both momentum entrainment and turbulent diffusion is enhanced by introducing the heated effluent as a high velocity jet. Hence in order to minimize dilution of the thermal plume the discharge structure should be designed to produce as low a discharge velocity of the condenser cooling water flow as possible. The conditions assumed for this case produce what I consider to be a practical minimum of mixing of the thermal plume with the receiving waters. Specifically, I have assumed a discharge orifice 500 ft. wide and 10 ft. deep, discharging into the surface layers of the Lake at a point where the water depth is at least 10 feet. This discharge orifice would result in a discharge velocity of the heated effluent of 0.30 ft/sec.

Case III: Discharge structure designed to produce a rate of dilution of the thermal plume by the receiving waters "typical" of many existing steam-generating electric plants. Specifically, I have assumed a discharge orifice 50 ft. wide and 10 ft. deep, discharging into the surface layers of the Lake at a point where the depth is at least 10 feet. This discharge orifice would result in a discharge velocity of the heated effluent of 3.0 ft/sec.

Case IV: Discharge structure designed to promote rapid dilution of the thermal plume by the receiving waters. The design criteria for the discharge structure assumed for this case do not represent the most optimum design criteria for producing the maximum dilution possible. However, they do represent criteria which can be met with reasonable engineering effort, and serve to indicate the type of thermal distribution which can be attained by using the basic design principles which have been applied to the discharge structures of a number of power plants now under construction or in the planning stage. These include the Surry Nuclear Power Station on the James River estuary, the Morgantown Power Plant on the Potomac River estuary, the Calvert Cliffs Nuclear Power Plant on the Chesapeake Bay, the Pilgrim Nuclear Power Station on Cape Cod Bay, and the Zion Nuclear Power Station on Lake Michigan. Specifically, I have assumed a discharge orifice 15 feet wide and 10 feet deep, discharging into the surface layers of the Lake at a point where the water depth is at least 10 feet. This discharge orifice would result in a discharge velocity of the heated effluent of 10.1 ft/sec.

The computational model used to determine the probable distribution of excess temperature in the Lake waters adjacent to the point of discharge makes use of the most recent knowledge of momentum jet entrainment, turbulent diffusion, and surface cooling processes. It has been verified by comparison of computed vs. observed temperature distributions in the thermal plume adjacent to several existing power plants. One such comparison, that for the Waukegan Power Station on Lake Michigan, will be shown later in this statement.

Table I gives the results of these computations for the four cases described above, in terms of the area, in acres, contained within specific isotherms of excess temperature. These data are also shown in graphical form in Figure 1. Note that in this figure both the excess temperature and the area coordinates are on a logarithmic scale, in order to cover the large range of these variables.

The computational model also gives the length, width, and general shape of these areas contained within the specified isotherms, and hence the horizontal distribution of excess temperature in the surface layers of the Lake can be given in the form of contours of excess temperature on a schematic plan view of the Lake adjacent to the point of discharge, as shown in Figure 2. Since Case I does not represent a practically attainable situation, this case is not included in Figure 2.

Table 1

The Area, in Acres, Contained Within Specified Isotherms of Excess Temperature in the Thermal Plume Resulting from the Discharge of the Condenser Cooling Water Flow from a Steam-Electric Generating Plant, Rejecting 6.8×10^9 BTU/hr of Excess Heat at the Condensers, With a Temperature Rise of the Condenser Cooling Water Flow of 20°F, for Four Different Discharge Structure Designs as Described in the Text. (This Rate of Heat Rejection Corresponds to a Nominal 1000 MWE Nuclear Power Plant or to a Nominal 1700 MWE Fossil Fuel Plant at Present Efficiency Levels).

θ°F	Area, in Acres, for:			
Excess Temperature Isotherm	Case I	Case II	Case III	Case IV
14	3.78×10^2	1.66×10^2	1.9	0.2
10	7.71×10^2	5.42×10^2	7.1	0.6
5	1.66×10^3	2.57×10^3	1.11×10^2	10
3	2.36×10^3	3.19×10^3	4.65×10^2	44
2	2.94×10^3	3.26×10^3	1.00×10^3	99
1	3.90×10^3	3.29×10^3	3.47×10^3	3.91×10^2

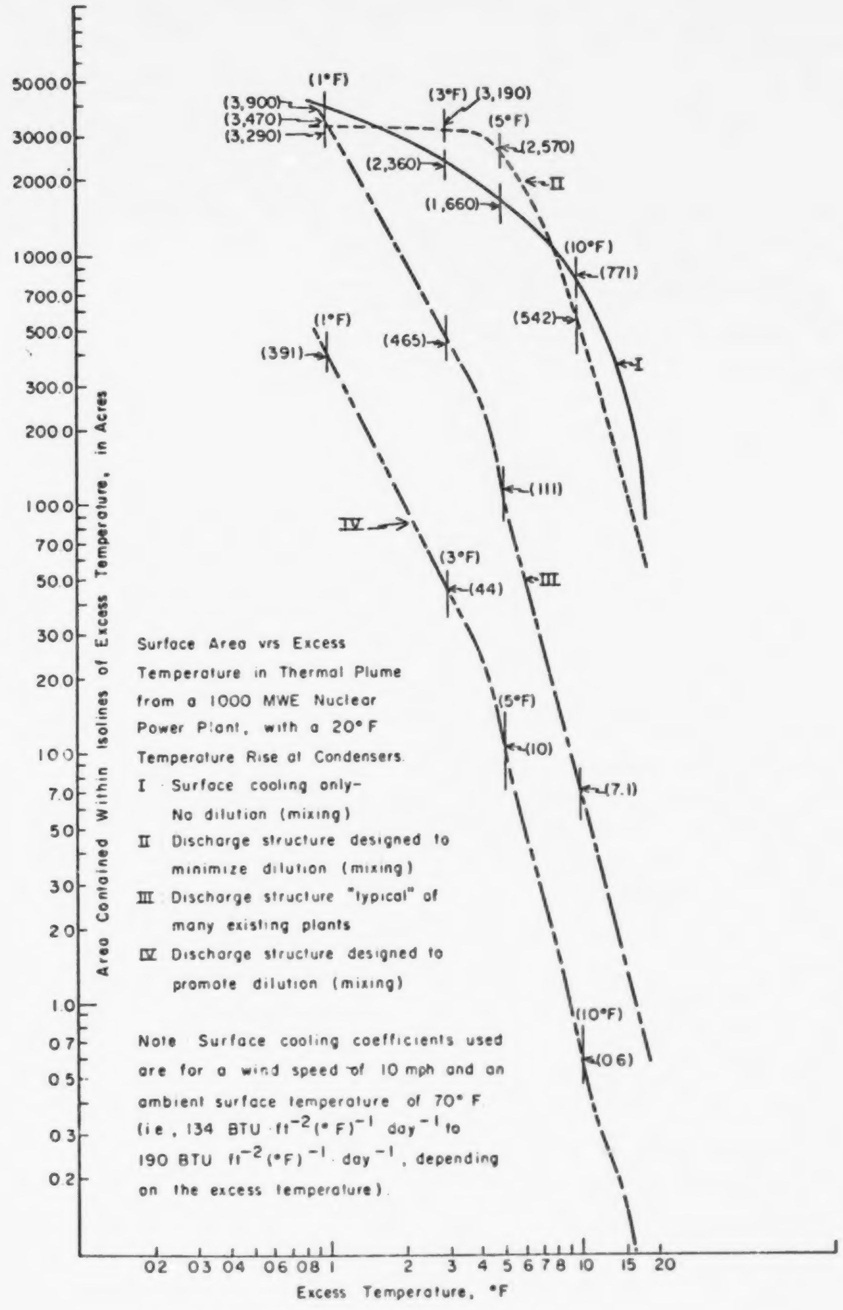

Area Contained Within Isolines of Excess Temperature, in Acres
5000.0
3000.0
2000.0
1000.0
700.0
500.0
300.0
200.0
100.0
70.0
50.0
30.0
20.0
10.0
7.0
5.0
3.0
2.0
1.0
0.7
0.5
0.3
0.2
0.2
0.3
0.4
0.6
0.8
1
2
3
4
5
6
7
8
10
15
20
Excess Temperature, °F
(1°F)
(3,900)
(3,470)
(3,290)
(3°F)
(3,190)
(5°F)
(2,570)
(2,360)
II
(1,660)
(10°F)
(771)
(1°F)
(465)
(542)
(391)
I
(111)
IV
(3°F)
(44)
III
Surface Area vrs Excess Temperature in Thermal Plume from a 1000 MWE Nuclear Power Plant, with a 20° F Temperature Rise at Condensers.
I Surface cooling only– No dilution (mixing)
II Discharge structure designed to minimize dilution (mixing)
III Discharge structure "typical" of many existing plants
IV Discharge structure designed to promote dilution (mixing)
(5°F)
(10)
(7.1)
Note Surface cooling coefficients used are for a wind speed of 10 mph and an ambient surface temperature of 70° F (i.e., 134 BTU ft⁻² (°F)⁻¹ day⁻¹ to 190 BTU ft⁻² (°F)⁻¹ day⁻¹, depending on the excess temperature).
(10°F)
(0.6)

Figure 1

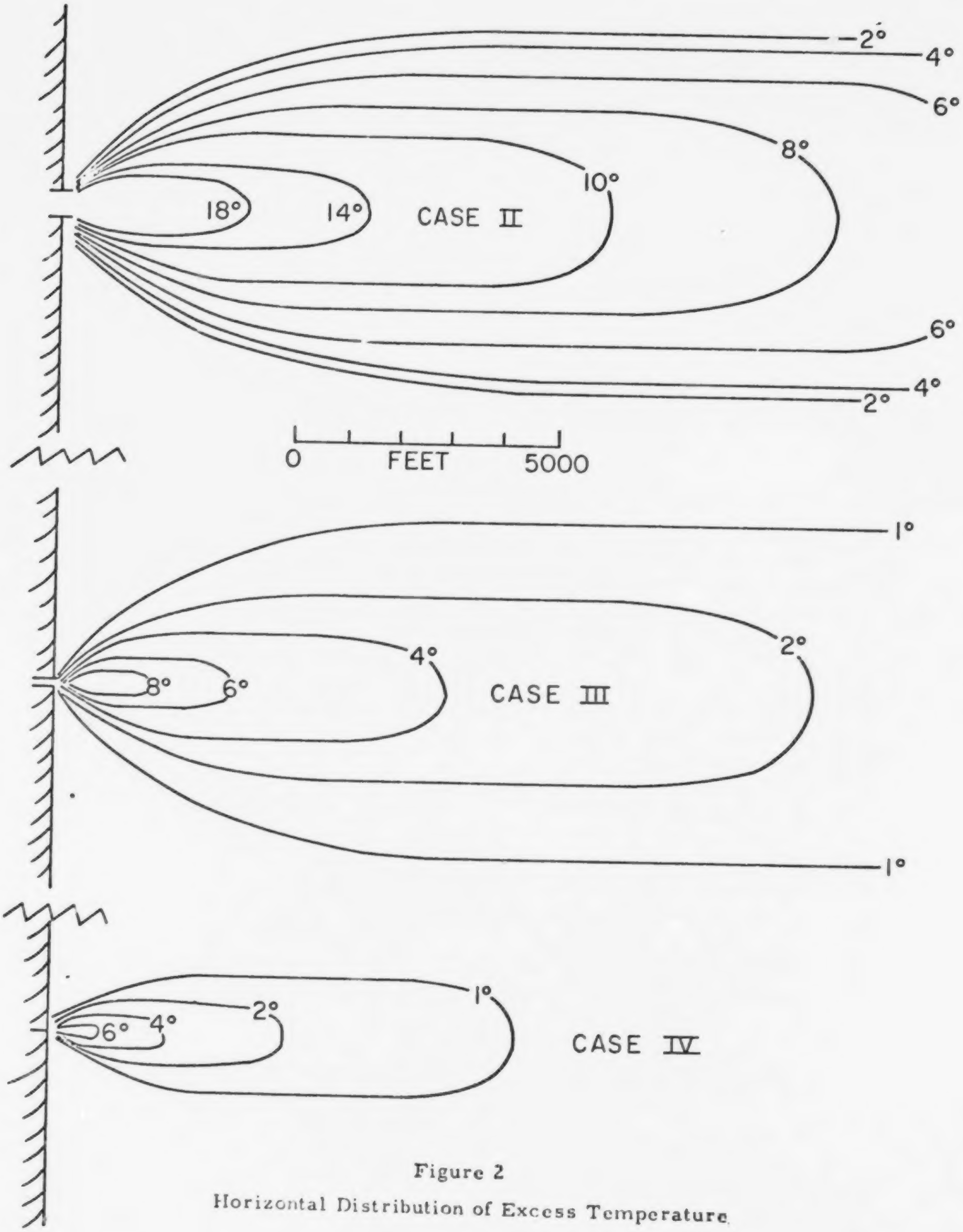


Figure 2
Horizontal Distribution of Excess Temperature

In all of the cases treated the excess heat would be primarily contained in the upper 10 to 15 feet of the surface layers of the Lake. Inspection of Table 1, and of Figures 1 and 2, clearly indicates that the areas contained within the specified isotherms of excess temperature, for all excess temperatures equal to or greater than 1°F, are significantly smaller for Case IV, for which the discharge structure design provided for rapid dilution of the thermal plume, than for Case II, for which the discharge structure design provide for minimizing dilution of the thermal plume. To relate these example computations to actual discharges of heated effluent into Lake Michigan, note that the thermal plume from the Zion Power Station will be somewhat smaller than that shown for Case IV. It is also worth noting that the dilution characteristic of many of the existing power plants (Case III) results in significantly smaller areas than for Case II, for excess temperature greater than 2°F.

Percent of Lake Surface Area Which Would Have Excess Temperatures Equal to or Exceeding Specified Values for an Unspecified Number of Steam-Electric Generating Plants Distributed Around the Lake Shoreline, Which Reject a Total of 3.50×10^{11} BTU/hr of Excess Heat, Corresponding to a Total Production of 51,500 MW (Nuclear) or 87,500 MW (Conventional)

Inspection of the data on temperature distribution in the thermal plume from a single power plant, such as that contained in Table 1 and in Figures 1 and 2, does not readily reveal the relative significance (in terms of areas affected by the heated discharges) of a number of power plants distributed around the Lake shoreline. In order to provide such a comparison, I have computed the areas, both in terms of acres and in terms of the percent of the Lake surface area, which would result from the use of the Lake waters for condenser cooling water flow, for a total power production of 51,500 MWE for nuclear fueled plants or 87,500 MWE for fossil fueled plants. At existing efficiency levels, these values for net electrical power production would correspond to a rate of rejection of excess heat of 3.50×10^{11} BTU/hr. In picking this particular figure for use in this illustrative example, I do not intend to indicate that this or any other value for the rate of rejection of heat from power plants located on the shores of Lake Michigan represents a contemplated, or necessarily an acceptable, total rate of rejection of waste heat. It does, however, represent about ten times the amount of waste heat now discharged into Lake Michigan. Also, as I showed earlier, this rate of heat rejection would produce a mean temperature rise of the surface layers of the Lake of only 0.1°F, a value sufficiently small so that, by taking reasonable precautions in plant location, interaction between thermal plumes from adjacent plants would be insignificant.

I have made these computations for the same four sets of design criteria as used in the previous section of this statement. The results of this evaluation are contained in Table 2. Note that in terms of the percent of the total area of the Lake Surface, the area contained within the relatively high isotherms of excess temperature are quite small for all four cases. Again, the considerable advantage of a design which promotes rapid dilution of the thermal plume is evident. Thus, for this case, less than four-hundredths of one percent of the surface area of the Lake would have excess temperatures exceeding 2°F, for a total power production of 51,500 MWE (nuclear) or 87,500 MWE (fossil fuel).

Temperature-Time of Exposure Relationships for Organisms Entrained into the Thermal Plume

A number of biologists who have studied the effects of temperature increases on aquatic and marine biota in the laboratory have been surprised to find, upon extending their studies to actual thermal discharges in natural water bodies, that the conclusions they had arrived at from their laboratory studies were not applicable to the real world. The major reasón for this apparent contradiction is that most laboratory studies have involved exposures of organisms to temperature increases for relatively long time periods. These

Table 2

Area, in Acres, and in Percent of Total Lake Surface Area, Having Excess Temperatures Equal to or Greater Than Specified Values, for an Unspecified Number of Nuclear Plants, Distributed Around the Shoreline of Lake Michigan, Which Discharge a Total of 3.50×10^{11} BTU/hr of Excess Heat, Corresponding to a Total Electric Production of 51,500 MWE (Nuclear) or 87,500 MWE (Fossil Fuel). Computed for a Temperature Rise at the Condensers of 20°F.

	Discharge Designed to Provide For:							
θ°F (Excess Temperature Isotherm)	Case I Zero Mixing - Surface Cooling only		Case II Minimum Mixing plus Surface Cooling		Case III Mixing "typical" of past Design of Power Plants		Case IV Efficient Mixing as per some current designs	
	Area Inside Isotherm θ, in		Area Inside Isotherm θ, in		Area Inside Isotherm θ, in		Area Inside Isotherm θ, in	
	Acres	% of Lake Area	Acres	% of Lake Area	Acres	% of Lake Area	Acres	% of Lake Area
14	1.95×10^4	0.14	8.55×10^3	0.06	98	0.00068	10.3	0.00007
10	3.97×10^4	0.28	2.79×10^4	0.20	3.65×10^2	0.0026	30.9	0.00022
5	8.56×10^4	0.60	1.32×10^5	0.96	5.72×10^3	0.040	5.25×10^2	0.0037
3	1.22×10^5	0.85	1.64×10^5	1.15	2.39×10^4	0.17	2.27×10^3	0.016
2	1.51×10^5	1.05	1.68×10^5	1.17	5.15×10^4	0.36	5.10×10^3	0.036
1	2.01×10^5	1.40	1.70×10^5	1.19	1.79×10^5	1.25	2.01×10^4	0.14

investigators failed to realize that the biologically important relationship to be investigated is the temperature-time exposure history. The discharge structures of many existing power plants provide for sufficiently rapid reduction of the temperature in the thermal plume due to dilution so that the laboratory data on mortality and other detrimental effects on organisms simply do not apply.

It is possible to develop relationships which give the maximum time of exposure to any specified temperature rise for organisms entrained into the thermal plume, for any specified set of discharge structure design criteria. I have used such relationships to compute the time-temperature relationships for each of the four cases of discharge design described earlier in this statement, for a nominal 1000 MWE nuclear power plant, or a 1700 MWE fossil fueled power plant, discharging 1520 cfs of condenser cooling water with a temperature rise at the condensers of 20°F. The results of these computations are shown in Table 3, in which the maximum time during which an organism entrained into the thermal plume would be subjected to excess temperatures equal to or greater than the listed values is given. These same data are shown in graphical form in Figure 3. Note that in Figure 3 both time and excess temperature are plotted on a logarithmic scale so as to provide for the large range of these two variables.

Note that the times of exposure given in Table 3 and plotted in Figure 3 are measured from the time of discharge of the heated effluent into the surface layers of the Lake. The time of transit of the condenser cooling water flow from the condensers to the point of discharge must be added to the times given in Table 3 and plotted on Figure 3 in order to obtain the total maximum time of exposure as a function of excess temperature for organisms which are entrained into the condenser cooling water intake flow and carried with the flow through the plant. For example, in the case of the Zion Power Station the time of transit of the condenser cooling water from the condensers to the point of discharge will be approximately 2 minutes. In order to minimize any

Table 3

Maximum Time of Exposure vs. Excess Temperature for Organisms Entrained Into the Thermal Plume Resulting from the Discharge of the Condenser Cooling Water Flow (1560 cfs, 20°F Temperature Rise) from a 1000 MWE (Nuclear) or a 1700 MWE (Fossil Fueled) Power Plant, for the Four Cases of Discharge Structure Design as Described in the Text.

	Time of Exposure For:			
Excess Temperature °F	Case I	Case II	Case III	Case IV
14	17 hr	6 hr	4 min	19 sec
10	32 hr	12 hr	9 min	47 sec
5	64 hr	36 hr	1.2 hr	6 min
3	88 hr	42 hr	5 hr	27 min
2	107 hr	43 hr	15 hr	1.5 hr
1	139 hr	44 hr	79 hr	11 hr

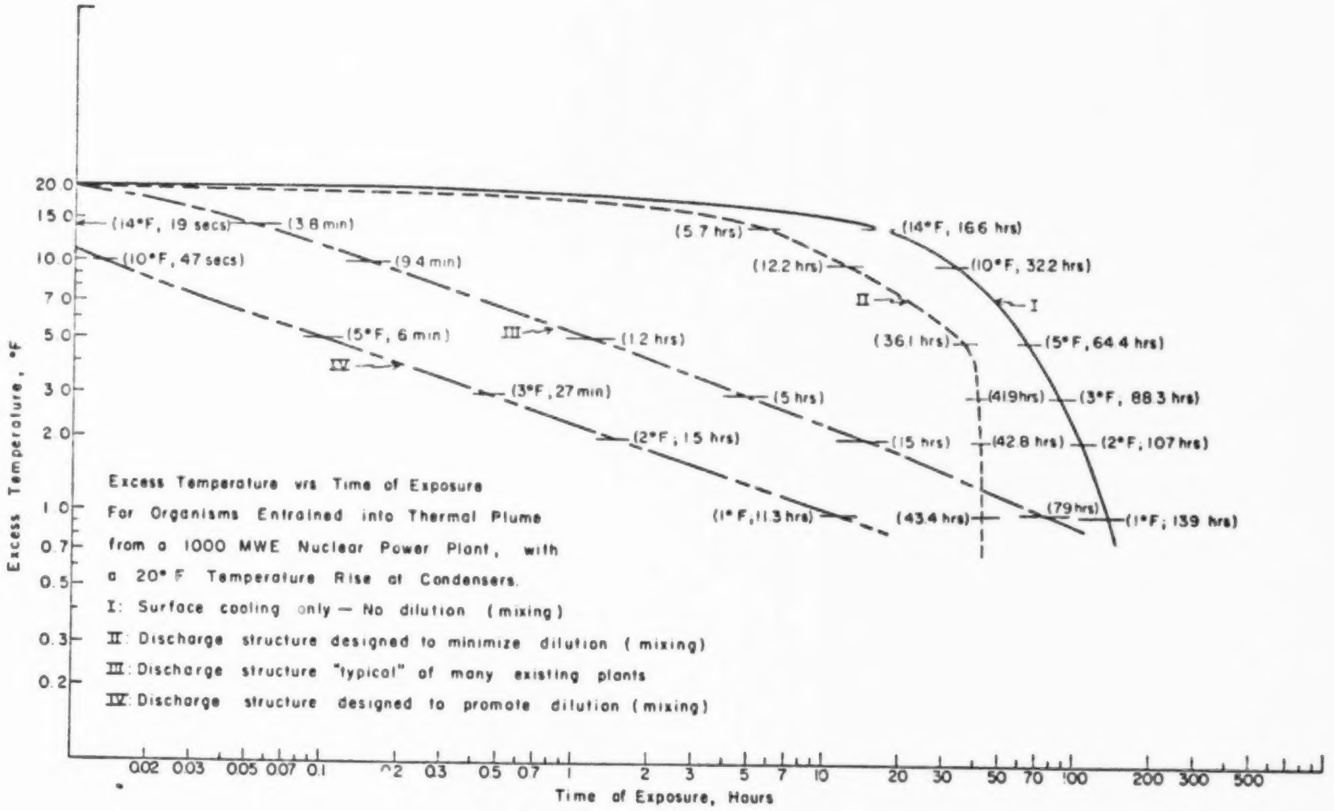

Excess Temperature, °F
20.0
15.0
10.0
7.0
5.0
3.0
2.0
1.0
0.7
0.5
0.3
0.2
Time of Exposure, Hours
.002 .003 .005 .007 0.1 .2 .3 .5 .7 1 2 3 5 7 10 20 30 50 70 100 200 300 500
Excess Temperature vrs Time of Exposure
For Organisms Entrained into Thermal Plume
from a 1000 MWE Nuclear Power Plant, with
a 20° F Temperature Rise at Condensers.
I: Surface cooling only — No dilution (mixing)
II: Discharge structure designed to minimize dilution (mixing)
III: Discharge structure "typical" of many existing plants
IV: Discharge structure designed to promote dilution (mixing)
I
II
III
IV
(14°F, 19 secs)
(3.8 min)
(5.7 hrs)
(14°F, 16.6 hrs)
(10°F, 47 secs)
(9.4 min)
(12.2 hrs)
(10°F, 32.2 hrs)
(5°F, 6 min)
(12 hrs)
(36.1 hrs)
(5°F, 64.4 hrs)
(3°F, 27 min)
(5 hrs)
(41.9 hrs)
(3°F, 88.3 hrs)
(2°F, 15 hrs)
(15 hrs)
(42.8 hrs)
(2°F, 107 hrs)
(1°F, 11.3 hrs)
(43.4 hrs)
(79 hrs)
(1°F, 139 hrs)

Figure 3

possible biological effects of using the surface waters of Lake Michigan for cooling, the condenser cooling water flow system should be designed to minimize the time of transit of the heated effluent from the condensers to the point of discharge.

An inspection of the data given in Table 3 shows that with respect to the time of exposure-temperature relationship, Case IV, for which the discharge structure design provided for rapid dilution of the thermal plume, has considerable advantage over designs which tend to minimize dilution. For example, organisms entrained into the thermal plume immediately after discharge of the heated effluent from a discharge structure designed to promote rapid dilution would be exposed to excess temperatures greater than 10°F for only 47 secs, and to excess temperatures greater than 5°F for only 6 minutes. The corresponding times of exposure for organisms entrained into the thermal plume immediately after discharge of the heated effluent from a discharge structure designed to minimize dilution are 12 hours and 36 hours respectively.

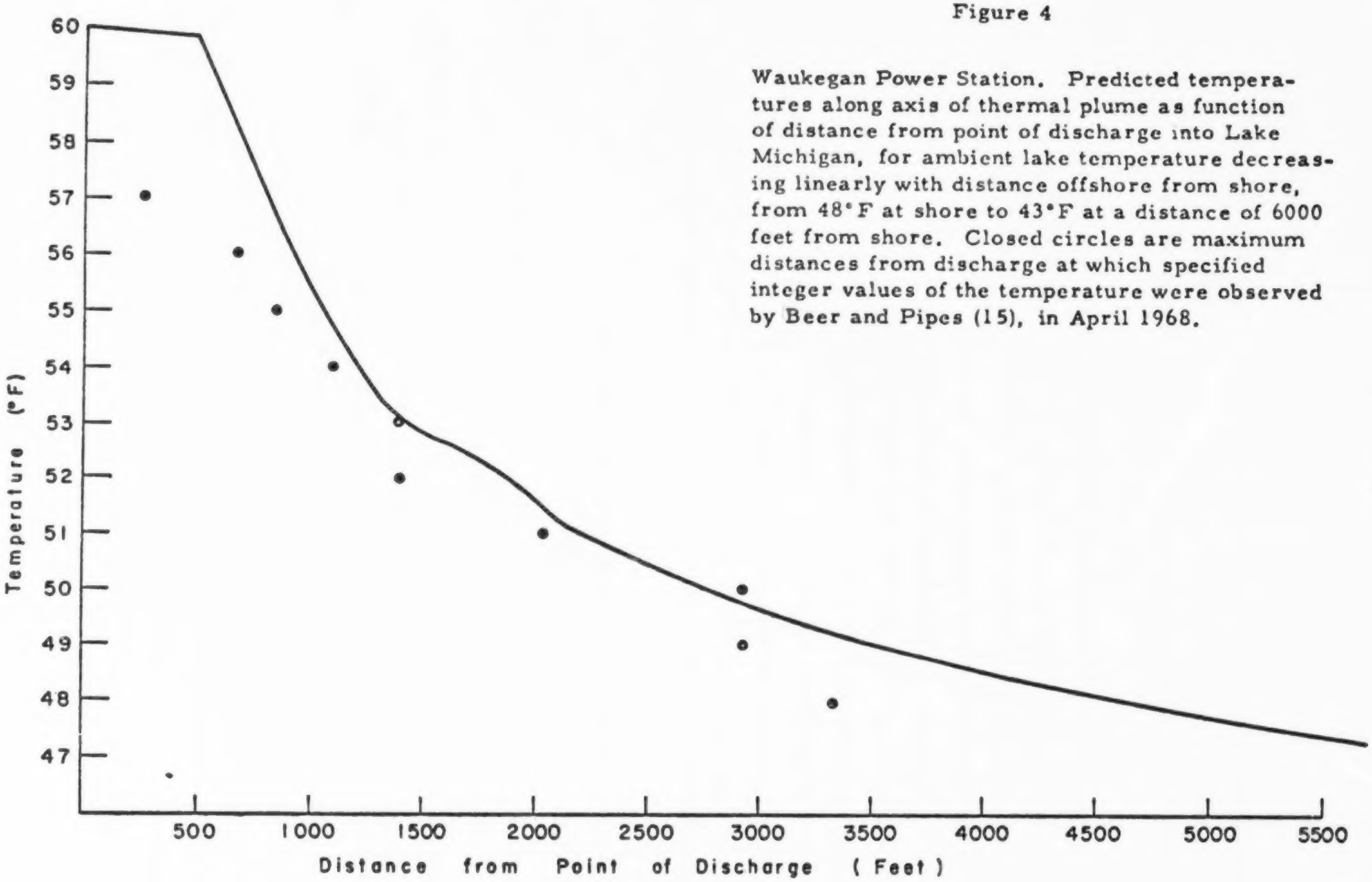
Comparison of Computed vs. Observed Temperatures in the Thermal Plume From the Waukegan Power Station

In order to demonstrate the validity of the computational model used in preparing the illustrative examples contained in this statement, I am including here a comparison of the predicted temperature distribution as computed using this model, with the observed temperature distribution in the thermal plume from the Waukegan Power Station. The observed data were obtained in a field survey carried out by Lawrence P. Beer and Wesley O. Pipes in April, 1968.

The comparison between the computed and the observed distributions is shown in Figures 4 and 5. In Figure 4 the solid curve represents the computed temperature as a function of distance along the axis of the thermal plume, while the closed circles are the maximum distances from the discharge at which the specified temperatures were observed by Beer and Pipes. Note

Figure 4

Waukegan Power Station. Predicted temperatures along axis of thermal plume as function of distance from point of discharge into Lake Michigan, for ambient lake temperature decreasing linearly with distance offshore from shore, from 48°F at shore to 43°F at a distance of 6000 feet from shore. Closed circles are maximum distances from discharge at which specified integer values of the temperature were observed by Beer and Pipes (15), in April 1968.



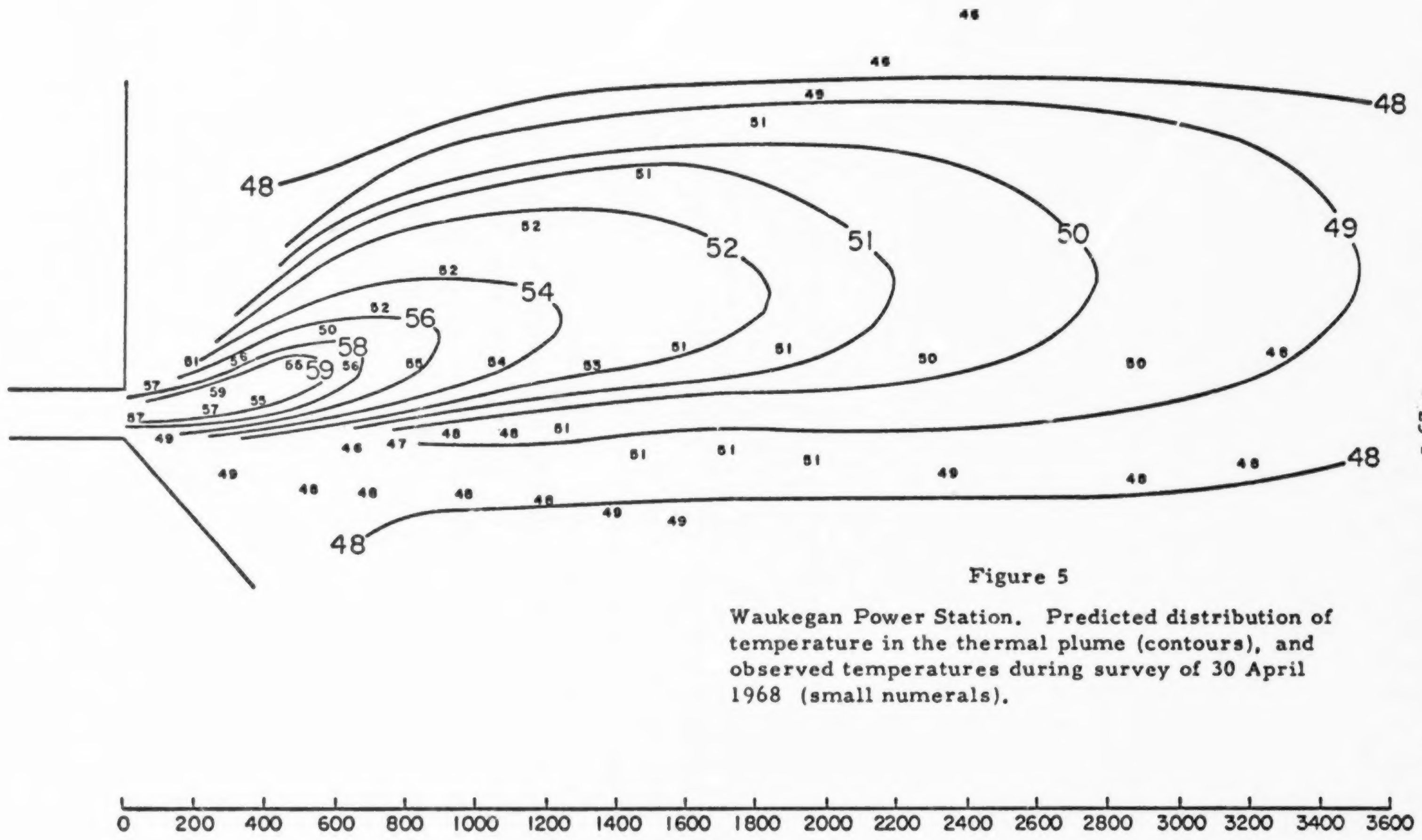


Figure 5

Waukegan Power Station. Predicted distribution of temperature in the thermal plume (contours), and observed temperatures during survey of 30 April 1968 (small numerals).

that in the field survey, temperatures were recorded only to the nearest whole degree, and at discrete positions in a network of stations which covered the plume area. Consequently it is to be expected that the predicted curve would represent an upper boundary for the observed data.

In Figure 5 the horizontal distribution of temperature in the thermal plume as predicted by the computational model is shown by the contours and the large numbers. The actual observations at the water surface are given by the small numbers. Again, taking into account the fact that the observed temperatures were recorded only to the nearest whole degree, the comparison between the computed and observed distributions is quite good.

Some Final Comments

I have investigated the circumstances associated with all mass mortalities of aquatic organisms which have been reported during the last five years as being caused by thermal shock, in large lakes, in tidal estuaries, and in coastal waters. In every such case, there is clear evidence that the primary cause of the mortality was not thermal. The largest mortalities were usually caused by fish, crabs or other swimming organisms being drawn against the trash racks and intake screens. The other cases resulted from the use of excessive amounts of antifouling chemicals. Proper design of the condenser cooling water flow system can completely eliminate these causes of mortality.

Several field studies have been undertaken to establish the biological effects of actual thermal discharges into natural water bodies. Some of these studies have been underway for over five years, and include studies made both before and after the initiation of the discharge of a heated effluent. None of these studies have demonstrated adverse effects of the heated discharge on the ecology of the receiving waterway. In most cases, a new or augumented sport fishery has been established in the thermal plume, as for, example at the Chalk Point Plant on the Patuxent River estuary and at the Connecticut Yankee Plant on the Connecticut River estuary.

On the basis of my experience and my calculations of heat exchange from the surface of Lake Michigan, I find that the discharge of condenser cooling water from the power plants currently proposed for Lake Michigan will have no measurable effect on the overall Lake temperature. I do find that even using the most conservative assumptions, the area of the thermal plume from a 1000 MWE nuclear power station having excess temperatures greater than 2°F would be less than 100 acres, and would have a maximum linear dimension of less than 1500 yards. I conclude that there is no scientific evidence to substantiate any need for a temperature standard of 1°F above ambient at the point of discharge but that, on the contrary, such a standard would lead to the waste of a valuable natural resource.

D. W. Pritchard
Consultant

September 1970

DONALD WILLIAM PRITCHARD

Biographical Data

Born: Santa Ana, California, October 20, 1922

Education: B. A. Degree in Meteorology, University of California at Los Angeles, 1943

M. A. (1948) and Ph. D. (1951) degrees in Oceanography, Scripps Institution of Oceanography, University of California, La Jolla, California

Present Employment: Director, Chesapeake Bay Institute, The Johns Hopkins University (since 1951); also Professor of Oceanography, Department of Earth and Planetary Sciences, The Johns Hopkins University

Past Professional Employment: Served as Weather Officer in World War II, forecasting sea and swell for amphibious landing operations in Normandy and in Pacific.

Head, Current Analysis Section, Scripps Institution of Oceanography, 1946

Oceanographer, U. S. Navy Electronics Laboratory, San Diego, California, 1947-48

Associate Director, Chesapeake Bay Institute, The Johns Hopkins University, 1949-1951

Chairman, Department of Oceanography, The Johns Hopkins University, 1950-1968

Professional Activities:

National Boards and Committees

Member, Committee on Oceanography, National Academy of Sciences (NASCO)
Chairman, Panel on Oceanographic Data (NASCO)
Member, Panel on Radioactivity in the Marine Environment (NASCO)
Member, Advisory Committee on Isotopes and Radiation Development, U. S. Atomic Energy Commission ,
Member, Marine Resources Advisory Committee, Department of the Interior

Professional Activities: (continued)

State Boards and Committees

Member, Board of Review, Department of Natural Resources, State of Maryland
Member, Air Quality Control Advisory Council, State of Maryland
Member, Radiation Control Advisory Board, State of Maryland
Member, Commission on Submerged Lands, State of Maryland
Member, Study Commission to Investigate Problems of Water Pollution in Maryland
Consultant to Special Commission on Pollution, State of Maryland

Professional Societies, Editorial Boards, and Honors

Fellow, American Geophysical Union; Past President, Past Vice President and Past Secretary, Section of Oceanography
Life Fellow, The International Oceanographic Foundation
Member, American Society of Limnology and Oceanography; Past Vice-President
Member, Society of Sigma Xi; Past President and Past Vice-President, JHU Chapter
Member, American Association for the Advancement of Science
Member, Atlantic Estuarine Research Society
Board of Editors, The Johns Hopkins Oceanographic Studies
Board of Editors, Journal of Marine Research

Past Professional Activities:

National Academy of Sciences Representative on the Advisory Board to the National Oceanographic Data Center, 1960-1968
Consultant to Special Advisory Committee to Department of Commerce, The National Academy of Sciences, 1959
Consultant, Sub-Committee on Oceanography and Fisheries, Committee on the Biological Effects of Atomic Radiation, National Academy of Sciences
Chairman, Panel on Waste Disposal from Nuclear Powered Ships, Committee on the Biological Effects of Atomic Radiation, National Academy of Sciences
Panel member - Radioactive Waste Disposal into the Sea, International Atomic Energy Agency, Vienna, Austria
Member, Ad Hoc Expert Committee on Radioactive Materials in Food and Agriculture, Food and Agricultural Organization of the United Nations, Rome, Italy

Consulting Experience:

Consultant to Virginia Electric and Power Company, 1954 to present; on projects related to limnology of impoundments for hydroelectric projects; water quality of hydroelectric plant discharge; distribution of excess temperature from conventional and nuclear powered thermal-electric plant discharges in lakes, rivers and estuaries; distribution of radioactive waste products discharged from nuclear power plants.

Consultant to Rochester Gas and Electric Company relative to distribution of excess heat and rad-waste products in Lake Ontario from the Brookwoo Nuclear Power Station. (1966)

Consultant to Florida Power and Light relative distribution of excess heat and rad-waste products in Biscayne Bay from the Turkey Point combined conventional-Nuclear Power Station. (current)

Consultant to Duke Power Company relative to limnology of hydroelectric impoundments and water quality of discharge from such impoundments.(1959)

Consultant to Pacific Northwest Power Company relative to stratification i and salmon migration through the proposed Nez Perse - High Mountain Sheep hydroelectric project.(1962)

Consultant to Bechtel Corporation relative to distribution of excess heat and rad-waste products from the Pilgrim Station Nuclear Power Plant, Boston Edison Company. (current)

Consultant to Philadelphia Electric Company relative to distribution of excess heat and rad-waste products in Conowingo Reservoir from Peachbottom Nuclear Power Station, Unit #1 (1960) and Units #2 and 3 (current)

Publications:

Author of some 50 scientific papers published in scientific journals, in symposia proceedings, in encyclopedia, and as chapters in text books, on such subjects as the physical oceanography of the Arctic and Antarctic; the physical limnology of lakes; the kinematics and dynamics of estuarine circulation and on the distribution of constituents in estuaries; the processes of diffusion in estuaries, coastal waters and in the ocean; the fate of radioactive materials in the marine environment; and the eutrophication of estuaries.

DR. PRITCHARD: One minor other point, Mr. Chairman. I will have some slides. I note that the viewability of these slides from the audience is detrimentally affected by this rather high intensive lamp over here to the left or to the right as you face the screen. I wonder if someone nearby might be permitted to turn the switch on that light. Also, we would afford a reduction in electric power.

Thank you.

My name is Donald W. Pritchard. I am Director of the Chesapeake Bay Institute and also Professor of Oceanography, Department of Earth and Planetary Sciences, The Johns Hopkins University. I hold a B.S. degree in meteorology and M.S. and Ph.D. degrees in oceanography. For the past 23 years I have conducted and directed research programs concerned with the movement and mixing of waters in lakes, estuaries, and marine coastal areas, and with the chemistry and biology of these water bodies. Investigations of the heat budget have been a part of my studies of the physical processes in natural water bodies and for the last 5 years I have concentrated on studies of the fate of excess heat discharged with the condenser cooling water flow from steam-electric generating plants. I have served as an advisor to Federal, State, and local government agencies concerning the fate of waste materials discharged into natural water bodies, and as a consultant to industry. In recent years, much of my consulting activities have been carried out as a partner in the firm of Pritchard - Carpenter, Consultants.

I have been concerned with the conservation and management of our natural resources for over 20 years. I was a member of the Board of Natural Resources of the State of Maryland for 12 years, and also served as Vice-Chairman of that Board. I am presently serving the State of Maryland as a member of the Board of Review, Department of Natural Resources; as a member of the Air Quality Advisory Board, State Health Department; and as a member of the Radiation Control Advisory Board. I have been a member of the Committee on Oceanography, National Academy of Sciences for the past 12 years, serving for some 6 years as chairman of the Panel on Radioactivity in the Marine Environment of that committee. I was also co-Chairman of the National Academy of Sciences, National Academy of Engineering Joint Workshop on Coastal Waste Management.

A curriculum vita is attached to this statement as an appendix. (See Pp. 786-788)

I was invited to present this statement by the

Commonwealth Edison Company, Chicago, Illinois. However, the opinions and conclusions I present here are my own, and do not necessarily represent the views of either The Johns Hopkins University or the Commonwealth Edison Company.

Lake Michigan as a Receiver of Condenser Cooling Water Discharge: A Natural Resource Which Can be Used Without Detrimental Effects on Other Uses of the Lake

A major purpose of my presentation here is to emphasize that Lake Michigan represents a great natural resource for cooling of water used in the generation of power, and that this resource can be used, with proper design of intake and discharge structures, without detrimental effects on other uses of the lake or on the natural biota of the lake. From the standpoint of the heat carried with the condenser cooling water discharge, Lake Michigan may be considered as a temporary receiver, since, independent of the method of introduction into the lake, virtually all of the heat rejected from steam-electric powerplants will be lost from the lake surface to the atmosphere. There is thus no permanent storage of the rejected heat in the lake; the excess heat resident in the lake at any given time is in transit, with the atmosphere at the ultimate destination.

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Temperature standards should be set to provide both for the protection of aquatic biota and for effective use of the resource of the lake as a heat transfer mechanism. Overly stringent temperature standards beyond those necessary for protection of the aquatic biota represent a waste of a natural resource. From the standpoint of the total economy, funds expended (that is wasted) in meeting unrealistic standards will not be available, in the long run, to serve in meeting other important environmental protection needs; for example, in the construction of adequate municipal waste treatment plants.

In addition to the seasonal variations in temperature, water bodies such as Lake Michigan are subject to natural variations in temperature associated with longer-term climatic fluctuations. Studies of other natural water bodies of comparable size in mid-latitudes have revealed that the annual mean temperature of the surface layers show a year-to-year variation compared to a mean over the last 50 years, having a range of nearly 7 degrees F.

Further, the mean temperature of the surface layers over periods as long as 10 years may vary from the long term (50 year) mean by 1.5 degrees F. Spatial

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variations in temperature of several degrees F. over distances of 1 or 2 miles are also characteristic of such natural water bodies. The natural biota will be conditioned to these natural fluctuations, and it is unlikely that man-induced temperature changes over any significant fraction of the lake surface which fall within these natural fluctuations will have any measurable effect on the ecology of the lake. I might add that I had the opportunity to read a paper which I understand Dr. C. H. Mortimer, Director of the Center for Great Lakes Study, University of Wisconsin, delivered at this workshop on Thursday in which Dr. Mortimer reviews his long period of studies of temperature from intakes and other sources in the Great Lakes and particularly in Lake Michigan. These studies demonstrate and support the contention that I have just made of very large or relatively large natural temperature fluctuations in Lake Michigan.

The quantitative expression giving the rate of change of heat content of a body of water such as Lake Michigan in terms of the difference between the radiation terms which add heat to the surface of the water body and the radiation terms which remove heat from the surface of the water body is called the heat budget of the lake. An examination of the various terms which enter the heat budget for Lake Michigan can serve as a basis for a consideration of the relative significance of the heat which might be discharged into the surface waters of the lake as a result of electric power generation. The heat budget states that the time rate of change in the amount of heat stored in the waters of the lake equals the rate of input of solar radiation to the surface of the lake, plus the rate of input of long-wave radiation from the atmosphere to the lake surface, minus the long-wave radiation emitted from the lake surface to the atmosphere, minus the heat loss from the lake surface to the atmosphere due to evaporation, minus the heat loss from the lake surface to the atmosphere due to conduction.

Since the heat concentration per unit volume is directly proportional to the temperature, the heat budget is also a statement of the time rate of change of temperature. Each of the radiation and heat exchange terms which enter the heat budget is individually much larger in magnitude than the algebraic sum of all of the terms at any given time. Thus the time changes in temperature in the surface waters of the lake, such as the diurnal or seasonal variations, result from a relatively small difference between several relatively large radiation terms in the heat budget. Since each of the terms in the

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heat budget vary in both space and time, natural variations in the temperature in the surface layers of the lake are to be expected.

Characteristic values of long-term averages of the terms in the heat budget for Lake Michigan are listed below, in units of B.t.u./hr. gained or lost at the water surface. Note that these terms are given for the total lake surface area.

Input of solar radiation to the lake surface equals 3.75×10^{13} B.t.u./hr. I might point out that this corresponds to 1440 B.t.u. per square foot per day, a value somewhat smaller than that given in the Department of Interior "white paper" which was 1735 B.t.u. per square foot per day.

The second term is the input of long-wave radiation from the atmosphere to the lake surface amounting to 7.50×10^{13} B.t.u./hr.

And the third is the loss of heat from the water surface due to back radiation, amounting to 9.38×10^{13} B.t.u./hr.

I might note also that in the Department of Interior "white paper," it is apparent that they considered as input only solar radiation. This is an improper treatment of the heat budget input of the lake, since the amount of energy added to the lake's surface from the input of long-wave radiation from the atmosphere into the lake surface is dependent primarily on atmospheric conditions and is the amount of water vapor primarily in the atmosphere.

The loss of long-wave radiation from the water surface back to the atmosphere and to space depends only on the temperature of the water surface.

The fourth term of the heat budget -- the second heat loss term is the loss of heat from the water surface due to evapoaration, amounting on the average to 1.56×10^{13} B.t.u./hr.

And finally, the loss of heat from the water surface due to conduction, amounting to 3.12×10^{12} B.t.u./hr.

Thus, on the average --

MR. STEIN: Just wait a moment. You know, this is kind of tough. I always try to get people to reduce to specific numbers. You run down times 10 to the 13th power four numbers, then you switch times 10 to the 12th.

Now, why can't you reduce that to a number that we can get instead of switching your coefficient.

DR. PRITCHARD: I am sorry if it is confusing to you, Mr. Stein.

MR. STEIN: I recognize you are sorry, but it is not confusing to me. It is not confusing to me at all, but it might be confusing to someone else.

Why did you shift your coefficient and why couldn't you use regular numbers and work this out?

DR. PRITCHARD: Well, to me these are regular numbers. To ease your confusion, the last number is --

MR. STEIN: Why do you insist you are going to ease my confusion?

DR. PRITCHARD: Mr. Stein, I am not here to argue with you. I am here to present some facts for consideration of the conferees and if you would allow me to continue I will do so.

The last thing --

MR. BANE: I suggest I think the witness ought to be allowed to proceed with his paper.

MR. STEIN: He will.

DR. PRITCHARD: The last number expressed to the same coefficient as the others is $.312 \times 10^{13}$ B.t.u.

MR. STEIN: In other words, it is a typographical error?

DR. PRITCHARD: No. 3.12×10^{12} B.t.u./hr. is the same as 0.312×10^{13} B.t.u./hr.

MR. STEIN: Thank you. You may proceed. That is correct.

DR. PRITCHARD: Thus, on the average, solar radiation and long-wave radiation from the atmosphere provide a heat input to the surface of Lake Michigan of some 11.25 x 10^{13} B.t.u./hr.; while the processes of back radiation, evaporation, and conduction of sensible heat produce a rate of loss of heat from the lake surface totaling about 11.25 x 10^{13} B.t.u./hr. In other words, on the average, the input heat terms and the input heat loss terms are in balance.

By way of comparison, the rate of rejection at the condensers of a 1,000 MWe nuclear power station, or a 1,700 MWe fossil-fueled power station. at existing efficiencies, is 6.8 x 10^9 B.t.u./hr., or 6/1,000 of 1 percent of the average rate of heat input to the surface layers of the lake due to solar radiation and atmospheric radiation.

I might add that the heat rejected from 51,500 MWe nuclear or 87,500 MWe fossil fuel is 3.5 x 10^{11} B.t.u./hr. or a rejection rate 10 times the present input to the lake represents only 3/10 of 1 percent of the average heat input to the lake from natural sources.

As I will demonstrate later in this statement,

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the most effective way that Lake Michigan can be used as a receiver of waste heat is through a combination of efficient dilution -- that is mixing -- of the heated effluent with the surface layers of the lake, plus loss of excess heat to the atmosphere through surface cooling.

To demonstrate the potential capacity of Lake Michigan to receive condenser cooling water discharges, I have computed the mean temperature rise of the surface layers of the lake which would result from the discharge of the condenser cooling water flow from an unspecified number of powerplants distributed around the lake shore, having a given total rate of heat rejection at the condensers of these plants and producing a given total net electric power.

This illustrative computation is made assuming "perfect" mixing of the discharged excess heat into the surface layers of the lake, that is the upper 10 feet, and subsequent excess heat balance due to surface cooling and advective discharge from the lake. Admittedly, the assumption of "perfect" mixing of the heated effluent into the surface layers of the lake is unrealistic. Departures from this ideal assumption for actual discharges of heated effluent would result in local areas having excess temperatures exceeding those calculated in this illustrative example, and also large areas of the lake having excess temperatures less than those calculated here. Later in this statement I will give examples of the local distribution of excess temperature in the thermal plume which would result from specified design criteria for the discharge structures of a powerplant.

I have used the expression "excess temperature," and it would be well to clearly state what I mean by this expression. Designating the natural or ambient temperature which would occur at a given location in the surface layers of the lake at a given time, under conditions of no discharge of heated effluent, by T_n, and designating the temperature which would occur at that same location and time under conditions of discharge of heated effluent by T_h, then the excess temperature, Θ (Greek letter Theta) is given by the difference between T_h and T_n. That is, $\Theta = T_h$ minus T_n.

The necessary input data for this illustrative computation are:

1) The surface area of the lake, which I have taken from available publications to be 14.33 million acres:

2) The average annual volume rate of outflow from the lake, which I have taken from available publications to be 39,000 ft.^{3}/sec.;

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3) The surface cooling coefficient for the lake, which I have taken here to equal 135 B.t.u./ft.^{2}/(°F.)/day, a value corresponding to a wind speed of 10 m.p.h., an ambient temperature of 70° F., and an excess temperature between zero and 1.0° F.

I might point out that in the text you have there is a typographical error. The number 161 should be 135.

4) The relationship between net electric power production and the rate of rejection of excess heat at the condensers. In this illustrative computation I have used two values for this latter relationship; that is, I have assumed efficiencies now possible for nuclear power production (6.8×10^6 B.t.u./hr. rejected heat per MWe produced power); and efficiencies now realized in fossil-fueled powerplants (4.0×10^6 B.t.u./hr. rejected heat per MWe produced power).

The following table gives the results of this computation in terms of the total rate of rejected excess heat and total net electric power production from an unspecified number of powerplants distributed around the shoreline of the lake, for the stated values of mean excess temperature in the surface layers. (See P. 764)

I would point out that in particular the second line in that table, which indicates that for a total heat rejection of 3.5×10^{11}, which is approximately ten times the current amount of heat rejected from the powerplants into the surface waters of Lake Michigan, that this total rate of heat rejection would correspond to the mean temperature rise in the surface layers of the lake 1/10 of 1 degree F. This would correspond to the stated figures of 51,500 MWe total power production if the -plants were nuclear or 87,500 MWe, if the powerplants were fossil-fueled.

From this table it is clear that Lake Michigan has the capacity, under ideal conditions of mixing, to receive the excess heat rejected during the production of relatively large amounts of electric power, with only very small increases in the mean temperature of the surface layers of the lake.

It should again be emphasized that the assumption of perfect mixing of the heated effluent into the surface layers of the lake cannot be realized in the actual environment. Departures from this idealized situation for actual discharges of condenser cooling water would result in localizing any temperature increases above ambient. Thus, this example computation demonstrates that the temperature rise in the surface layers of the lake as a whole, resulting from the discharge into these waters of the condenser cooling water flow from a total net electric power production exceeding any reasonable projection of power requirements in the foreseeable future, would be sufficiently small so as to have no detrimental effects on other uses of the lake, or on the natural biota of the lake. Any possible detrimental effect of the discharge of heated effluent into the surface layers of the lake must therefore be of a local nature, occurring only in the vicinity of the point of discharge.

It is therefore desirable to examine the character of the local disturbance of the natural temperature regime resulting from the discharge of waste heat into the surface waters of Lake Michigan, for several different sets of design criteria for the discharge structure.

Distribution of Excess Temperature in the Thermal Plume From a Steam-Electric Powerplant Rejecting 6.8×10^9 B.t.u./hr. of Excess Heat to the Surface Layers of Lake Michigan, Corresponding to a Nominal 1,000 MWe Nuclear Powerplant or to a 1,700 MWe Fossil-Fueled Powerplant

The distribution of excess temperature in the thermal plume resulting from the discharge of condenser cooling water from a steam-electric generating plant depends upon three processes. These are:

1) Dilution due to momentum entrainment of

cooler receiving water into the dispersing thermal plume;

2) dilution due to natural mixing processes, or turbulent diffusion of the heated effluent into the cooler receiving waters; and

3) transfer of excess heat from the water to the atmosphere across the air-water interface due to surface cooling.

Observations of the temperature distribution in thermal plumes resulting from the horizontal discharge of heated effluent into the surface waters of Lake Michigan as well as other similar water bodies reveal that the excess heat is primarily confined to a surface layer 10 to 15 feet in vertical thickness. The actual depth to which measurable increases in water temperature above ambient may be observed depends upon the depth of the water at the point of discharge, critical design features of the discharge orifice, the slope of the bottom offshore from the point of discharge, and the natural vertical gradient in the ambient temperature field. However, experience has shown that the probable distribution of excess temperature in a thermal plume within the surface layers of Lake Michigan resulting from the horizontal discharge of a heated effluent may be computed with reasonable confidence using a prediction model in which it is assumed that the excess heat discharged with the condenser cooling water flow is confined within a dispersing thermal plume extending from the surface to a depth of approximately 10 feet. Vertical entrainment of dilution water into the thermal plume is included in the prediction model only when the design of the discharge orifice is such that the initial vertical dimension of the discharged jet is less than 10 feet.

The excess temperatures computed using this numerical predicting model apply to the water surface. It is also assumed that there is no vertical variation in temperature in the upper 10 feet. As pointed out above, actual observations in thermal plumes in Lake Michigan show that the excess temperature is a maximum at the surface, and decreases with depth. Measurements made in the thermal plume adjacent to the Waukegan Power Station show that a thermal plume at a depth of 10 feet is significantly smaller than at the surface, and that the temperatures at a depth of 15 feet are not measurably larger than the ambient temperature. Thus the areas contained within specified isotherms of excess temperatures as computed from the numerical prediction model used here are larger than would actually occur for all subsurface depths.

Field studies of actual thermal plumes, as well as laboratory studies involving the horizontal discharge of a heated jet into a water flume reveal that within the constraints of practical design for the large majority of real or potentially real situations, the primary mechanism producing the initial decrease in excess temperature is dilution of the thermal plume by horizontal momentum entrainment of the cooler receiving waters. Dilution by the natural mixing processes becomes important only after the initial mechanical dilution of the thermal plume by momentum entrainment has altered the transverse temperature distribution from a nearly flat-topped structure to a sharply bell-shaped structure. Existing evidence indicates that natural turbulent diffusion becomes a dominant process in controlling the distribution of excess temperature in the thermal plume after the plume has been diluted by momentum entrainment by a factor of about fivefold.

The rate at which excess heat is lost from the water to the atmosphere per unit surface area is directly proportional to the excess temperature at the surface. The proportionality factor relating the excess temperature to the rate of loss of excess heat per unit surface area is called the surface cooling coefficient. Its value depends primarily upon the wind velocity, secondarily on the ambient temperature, and to a lesser extent on the actual excess temperature. For practical purposes, within the normal range of excess temperatures, the dependence of the surface cooling coefficient on the excess temperature may usually be neglected.

This coefficient has the units of heat flux through a unit surface area per unit of excess temperature per unit of time; for example, in B.t.u./ft.^{2}/(°F.)/hr. The surface cooling coefficient increases with increasing wind speed, with increasing ambient temperature, and with increasing excess temperature, with the dependence on wind speed being the most important.

The fact that the rate of loss of excess heat from the water to the atmosphere per unit area of water surface is greater the larger the excess temperature, has led to the rather widely held opinion that the most effective way to use a natural body of water as a receiver of waste heat is to introduce the heated effluent into the surface layers of the water body in a manner designed to prohibit, or at least minimize, dilution of the heated effluent by the cooler receiving waters. The rate of loss of excess heat from areas having relatively high excess temperatures would thus be maximized, and the area of the lake surface within which measurable temperature rises would occur would be minimized.

An alternate hypothesis is that the most effective way to use a natural water body such as Lake Michigan as a receiver of waste heat is to design the discharge structure for the introduction of the heated effluent into the surface layers of the lake in such a way that dilution of the thermal plume by momentum entrainment and natural turbulent diffusion is maximized. In this scheme the dilution capacity of the receiving waters of the lake adjacent to the point of discharge of the heated effluent is used to the maximum extent practically possible. The excess temperature in the thermal plume is thus reduced rapidly by dilution. Heat loss to the atmosphere occurs for the most part from relatively large areas of very small excess temperature.

Both laboratory studies of heated jets discharged into a flowing water flume, and field studies of thermal plumes in natural water bodies, reveal that when a heated effluent is discharged at the shoreline into a transverse, longshore ambient current, the thermal plume is bent in a downcurrent direction to become parallel to the shoreline. Consequently, the supply of low temperature dilution water is cut off on the inshore side of the thermal plume, and the rate of dilution of the plume is significantly reduced as compared to the case of discharge into the receiving body of water in the absence of an ambient longshore current. If, however, the discharge is made from a structure located sufficiently far offshore, and the discharge pipelines are buried below the bottom of the waterway between the shoreline and the point of discharge, free flow of dilution water on the inshore side of the thermal plume occurs even in the presence of an ambient longshore current. Consequently, the rate of dilution in the bent jet discharged offshore approaches that which occurs in a thermal plume discharged into a water body having no longshore currents.

The following four example computations serve to provide a comparison between the distributions of excess temperature in the thermal plumes resulting from the discharge of condenser cooling water via discharge structures designed either to minimize dilution of the heated effluent or to promote such dilution. In each of the four cases described below it is assumed that a steam-electric generating plant rejecting 6.8 x 10^9 B.t.u./hr. of excess heat at the condenser discharges the heated condenser cooling water into the surface layers of Lake Michigan. This rate of heat rejection corresponds to a nominal 1,000 MWe nuclear powerplant or to a nominal 1,700 MWe fossil fuel powerplant at present efficiency levels. It is further assumed that the temperature rise of the condenser cooling water flow at the condensers is 20 degrees Fahrenheit, and hence the required volume rate of flow of condenser cooling water is 1,520 $ft.^3/sec.$ In all cases it is also assumed that the heated effluent is discharged into a waterway having no longshore currents, or that the discharge structure is located far enough offshore so that free passage of dilution water can occur on the inshore side of the bent thermal plume even in the presence of a longshore current.

Case I: Discharge structure designed so that no dilution (mixing) of the heated effluent with the receiving waters of the lake occurs. Hence the decrease in excess temperature occurs as a result of surface cooling only. It should be recognized that it is in fact impossible to discharge the condenser cooling water flow into the lake without some mixing between the heated effluent and the cooler receiving waters. However, it is of some interest to consider this case for purpose of comparison.

Case II: Discharge structure designed to minimize dilution of the heated effluent by the cooler receiving waters of the lake. Dilution of the thermal plume by both momentum entrainment and turbulent diffusion is enhanced by introducing the heated effluent as a high velocity jet. Hence in order to minimize dilution of the thermal plume the discharge structure should be designed to produce as low a discharge velocity of the condenser cooling water flow as possible. The conditions assumed for this case produce what I consider to be a practical minimum of mixing of the thermal plume with the receiving waters. Specifically, I have assumed a discharge orifice 500 feet wide and 10 feet deep, discharging into the surface layers of the lake at a point where the water depth is at least 10 feet. This discharge orifice would result in a discharge velocity of the heated effluent of 0.30 feet per second.

Case III: Discharge structure designed to produce a rate of dilution of the thermal plume by the receiving waters "typical" of many existing steam-generating electric plants. Specifically, I have assumed a discharge orifice 50 feet wide and 10 feet deep, discharging into the surface layers of the lake at a point where the depth is at least 10 feet. This discharge orifice would result in a discharge velocity of the heated effluent of 3.0 feet per second.

Case IV: Discharge structure designed to

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promote rapid dilution of the thermal plume by the receiving waters. The design criteria for the discharge structure assumed for this case do not represent the most optimum design criteria for producing the maximum dilution possible. However, they do represent criteria which can be met with reasonable engineering effort, and serve to indicate the type of thermal distribution which can be attained by using the basic design principles which have been applied to the discharge structures of a number of powerplants now under construction or in the planning stage. These include the Surry Nuclear Power Station on the James River estuary, the Morgantown Power Plant on the Potomac River estuary, the Calvert Cliffs Nuclear Power Plant on the Chesapeake Bay, the Pilgrim Nuclear Power Station on Cape Cod Bay, and the Zion Nuclear Power Station on Lake Michigan. Specifically, I have assumed a discharge orifice 15 feet wide and 10 feet deep, discharging into the surface layers of the lake at a point where the water depth is at least 10 feet. This discharge orifice would result in a discharge velocity of the heated effluent of 10.1 feet per second.

The computational model used to determine the probable distribution of excess temperature in the lake waters adjacent to the point of discharge makes use of the most recent knowledge of momentum jet entrainment, turbulent diffusion, and surface cooling processes. It has been verified by comparison of computed versus observed temperature distributions in the thermal plume adjacent to several existing powerplants. One such comparison, that for the Waukegan Power Station on Lake Michigan, will be shown later in this statement.

Table 1 (See P. 772) gives the results of these computations for the four cases described above, in terms of the area, in acres, contained within specific isotherms of excess temperature. These data are also shown in graphical form in Figure 1. (See P. 773) Note that in this figure both the excess temperature and the area coordinates are on a logarithmic scale, in order to cover the large range of these variables.

The computational model also gives the length, width, and general shape of these areas contained within the specified isotherms, and hence the horizontal distribution of excess temperature in the surface layers of the lake can be given in the form of contours of excess temperature on a schematic plan view of the lake adjacent to the point of discharge, as shown in Figure 2 (See P. 774). Since Case I does not represent a practically attainable situation, this case is not included in Figure 2.

In all of the cases treated the excess heat would be primarily contained in the upper 10 to 15 feet of the surface layers of the lake. Inspection of Table 1, and of Figures 1 and 2, clearly indicates that the areas contained within the specified isotherms of excess temperature, for all excess temperatures equal to or greater than 1 degree Fahrenheit are significantly smaller for Case IV, for which the discharge structure design provided for rapid dilution of the thermal plume, than for Case II, for which the discharge structure design provide for minimizing dilution of the thermal plume. To relate these example computations to actual discharges of heated effluent into Lake Michigan, note that the thermal plume from the Zion Power Station will be somewhat smaller than that shown for Case IV. It is also worth noting that the dilution characteristic of many of the existing powerplants (Case III) results in significantly smaller areas than for Case II, for excess temperature greater than 2 degrees Fahrenheit.

Percent of Lake Surface Area Which Would Have Excess Temperatures Equal to or Exceeding Specified Values for an Unspecified Number of Steam-Electric Generating Plants Distributed Around the Lake Shoreline, Which Reject a Total of 3.50×10^{11} B.t.u./hr. of Excess Heat,

Corresponding to a Total Production of 51,500 MW (Nuclear) or 87,500 MW (Conventional)

Inspection of the data on temperature distribution in the thermal plume from a single powerplant, such as that contained in Table 1 and in Figures 1 and 2, does not readily reveal the relative significance (in terms of areas affected by the heated discharges) of a number of powerplants distributed around the lake shoreline. In order to provide such a comparison, I have computed the areas, both in terms of acres and in terms of the percent of the lake surface area, which would result from the use of the lake waters for condenser cooling water flow, for a total power production of 51,500 MWe for nuclear-fueled plants or 87,500 MWe for fossil-fueled plants. At existing efficiency levels, these values for net electrical power production would correspond to a rate of rejection of excess heat of 3.50×10^{11} B.t.u./hr. In picking this particular figure for use in this illustrative example, I do not intend to indicate that this or any other value for the rate of rejection of heat from powerplants located on the shores of Lake Michigan represents a contemplated, nor necessarily an acceptable, total rate of rejection of waste heat. It does, however, represent about ten times the amount of waste heat now discharged into Lake Michigan. Also, as I showed earlier, this rate of heat rejection would produce a mean temperature rise of the surface layers of the lake of only .1 degree F., a value sufficiently small so that, by taking reasonable precautions in plant location, interaction between thermal plumes from adjacent plants would be insignificant.

I have made these computations for the same four sets of design criteria as used in the previous section of this statement. The results of this evaluation are contained in Table 2. (See P. 777) Note that in terms of the percent of the total area of the lake surface, the area contained within the relatively high isotherms of excess temperature are quite small for all four cases. Again, the considerable advantage of a design which promotes rapid dilution of the thermal plume is evident. Thus, for this case, less than 4/100 of 1 percent of the surface area of the lake would have excess temperatures exceeding 2 degrees F. for a total power production of 51,500 MWe (nuclear) or 87,500 MWe (fossil fuel).

This incidentally represents less than 16/100 percent of the inshore area shown as defined by the Department of Interior "white paper."

I might pause to point out that the areas contained within the specified isotherms of excess temperature from my Case IV are considerably less than those given in Table 14, Page 45 of the Department of Interior "white paper" in which they made use or misuse of a computation I had previously made for a proposed discharge of heated effluent into Lake Erie. The reason that it was impossible to translate those calculations I made for Lake Erie to Lake Michigan are as follows:

One, the introduction of the heated effluent in the case taken by the authors of the Department of Interior "white paper," in using my calculations, was the case for a shoreline discharge made into a section of the lake which is relatively shallow, and the depth at the point of discharge being only 6 feet, and was made in the presence of a relatively large longshore current, which bent the discharge plume alongshore in the downcurrent direction and denied the inshore side of the plume dilution water from the free flow **of** the ambient current.

As I have pointed out, this condition can be corrected. I simply located a discharge point offshore, so that the cooling level of receiving waters can freely flow inside the discharge point and provide dilution water both for the inshore side and the offshore side of the bent thermal plume, and in this case the areas contained within the specified isotherms would be as those given in my Case IV.

Further, the authors of the Department of Interior "white paper" have chosen to use some interim results in the step-wise procedure of my computation, i.e., the computational procedure in the use of predicting model involves the prediction of the areas in the absence of cooling and then the correction of these areas for surface cooling. The values of the areas without surface cooling are interim steps in the computation and do not represent any real phenomena and should not be used in translating those data to Lake Michigan.

There is clear evidence that cooling occurs at all times. We refer back to the heat budget of the lake. There were two input terms and three heat loss terms. Now, any additional input term would have no effect on the other two input terms, but would affect the rate of cooling or the rate of the loss, since any increase in temperature is reflected in an increase at all three cooling terms. Hence, neither the input of solar energy nor the input of longwave radiation from the atmosphere would be affected by an additional input of heat such as from a powerplant, but all of the cooling terms would be increased and hence there would be a compensating loss of heat which would limit the temperature rise in the surface layers.

Temperature-Time of Exposure Relationships for Organisms Entrained into the Thermal Plume

A number of biologists who have studied the effects of temperature increases on aquatic and marine biota in the laboratory have been surprised to find, upon extending their studies to actual thermal discharges in natural water bodies, that the conclusions they had arrived at from their laboratory studies were not applicable to the real world. The major reason for this apparent contradiction is that most laboratory studies have involved exposures of organisms to temperature increases for relatively long time periods. These investigators failed to realize that the biologically-important relationship to be investigated is the temperature-time exposure history. The discharge structures of many existing powerplants provide for sufficiently rapid reduction of the temperature in the thermal plume due to dilution so that the laboratory data on mortality and other detrimental effects on organisms simply do not apply.

It is possible to develop relationships which give the maximum time of exposure to any specified temperature rise for organisms entrained into the thermal plume, for any specified set of discharge structure design criteria. I have used such relationships to compute the time-temperature relationships for each of the four cases of discharge design described earlier in this statement, for a nominal 1,000 MWe nuclear powerplant, or a 1,700 MWe fossil-fueled powerplant, discharging 1,520 c.f.s. of condenser cooling water with a temperature rise at the condensers of 20 degrees F. The results of these computations are shown in Table 3, in which the maximum time during which an organism entrained into the thermal plume would be subjected to excess temperatures equal to or greater than the listed values is given. These same data are shown in graphical from in Figure 3. (See P. 779). Note that in Figure 3 both time and excess temperature are plotted on a logarithmic scale so as to provide for the large range of these two variables.

Note that the times of exposure given in Table 3 and plotted in Figure 3 are measured from the time of discharge of the heated effluent into the surface layers of the lake. The time of transit of the condenser cooling water flow from the condensers to the point of discharge must be added to the times given in Table 3 and plotted on Figure 3 in order to obtain the total maximum time of exposure as a function of excess temperature for organisms which are entrained into the condenser cooling water intake flow and carried with the flow through the plant. For example, in the case of the Zion Power Station the time of transit of the condenser cooling water from the condensers to the point of discharge will be approximately 2 minutes. In order to minimize any possible biological effects of using the surface waters of Lake Michigan for cooling, the condenser cooling water flow system should be designed to minimize the time of transit of the heated effluent from the condensers to the point of discharge.

An inspection of the data given in Table 3 shows that with respect to the time of exposure-temperature relationship, Case IV, for which the discharge structure design provided for rapid dilution of the thermal plume, has considerable advantage over designs which tend to minimize dilution. For example, organisms entrained into the thermal plume immediately after discharge of the heated effluent from a discharge structure designed to promote rapid dilution would be exposed to excess temperatures greater than 10 degrees F. for only 47 seconds, and to excess temperatures greater than 5 degrees F. for only 6 minutes. The corresponding times of exposure for organisms entrained into the thermal plume immediately after discharge of the heated effluent from a discharge structure designed to minimize dilution are 12 hours and 36 hours, respectively.

Now, Mr. Chairman, I have included in my statement a comparison of the model used -- which I have used in making these computations, and observed temperature distribution at the Waukegan power station. In the interest of time, I would pass over that unless there are specific questions concerning it and conclude with some final comments.

I have investigated the circumstances associated with all mass mortalities of aquatic organisms which have been reported during the last 5 years as being caused by thermal shock in large lakes, in tidal estuaries, and in coastal waters. In every such case there is clear evidence that the primary cause of the mortality was not thermal. The largest mortalities were usually caused by fish, crabs, or other swimming organisms being drawn against the trash racks and intake screens. The other cases resulted from the use of excessive amounts of antifouling chemicals. Proper design of the condenser cooling water flow system can completely eliminate these causes of mortality.

Several field studies have been undertaken to establish the biological effects of actual thermal discharges into natural water bodies. Some of these studies have been under way for over 5 years, and include studies made both before and after the initiation of the discharge of a heated effluent. None of these studies have demonstrated adverse effects of the heated discharge on the ecology of the receiving waterway. In most cases, a new or augmented sport fishery has been established in the thermal plume, as for example, at the Chalk Point Plant on the Patuxent River estuary and at the Connecticut Yankee Plant on the Connecticut River estuary.

On the basis of my experience and my calculations of heat exchange from the surface of Lake Michigan, I find that the discharge of condenser cooling water from the powerplants currently proposed for Lake Michigan will have no measurable effect on the overall lake temperature. I do find that even using the most conservative assumptions, the area of the thermal plume from a 1,000 MWe nuclear power station having excess temperatures greater than 2 degrees F. would be less than 100 acres and would have a maximum linear dimension of less than 1,500 yards. I conclude that there is no scientific evidence to substantiate any need for a temperature standard of 1 degree F. above ambient at the point of discharge but that, on the contrary, such a standard would lead to the waste of a valuable natural resource.

That completes my presentation, Mr. Chairman.

MR. STEIN: Thank you, Dr. Pritchard, for a very illuminating statement. You know, I am sorry I broke in on you.

DR. PRITCHARD: That is all right.

MR. STEIN: But you know I have had this problem -- particularly we have had it in radiation when they have given a number. When I say you confuse me, I am old enough to have taken the regular arts course and gone through considerable amounts of mathematics. But I have found when we give numbers -- and you have given a variety here -- and you have coefficients of 2 and 3 in your paper, 9, 11, 12, 13 -- these can cause great variance. I have asked the Federal people -- and we have done this with the radiation standards -- to stop that, to get this down to a number where we are communicating with everybody. The answer I got when I asked them why they were using 10 to the 9th power, 10 to the 11th power, was that people might not understand the numbers we are putting out and will misinterpret them. I said that is for the people to do. Let's give them a straight number and do the mathematics for them.

This is one of the campaigns that I have had for better understanding between the scientific community and the public by trying to do away with these coefficients. So, I wonder, do you think they have a reason, or why do we need these?

DR. PRITCHARD: Well, from my standpoint at least I wonder whether the nonmathematical individual any better understands a number like 3.75 or 37.5 trillion or 3.75 times 10 to the 13th.

MR. STEIN: No, when you change the coefficient, 10 to the 13th to 10 to the 11th and 10 to the 9th, we get a difference. You see they can make a judgment. What is larger or what is smaller if we use the same coefficient? But when you keep switching the coefficients on them, the people who are not sophisticated in mathematics don't even know if it is a larger or smaller number, and this is the thing I hope we can get together on.

As a matter of fact, if we are going to sell our program -- and this applies to the university program as well as the industrial program or the governmental program -- I think we have to begin communicating with the public, and if we shift the coefficients on our multiplier I am not sure we are communicating.

I don't know whether you want to answer that or not.

DR. PRITCHARD: I would just advise the public here that 10 to the 9th is larger than 10 to the 6th --

(Laughter) -- by a few thousand.

MR. STEIN: By what, 1,000?

DR. PRITCHARD: By a factor of a 1,000.

MR. STEIN: By a factor of a 1,000.

How many people knew that other than your experts?

... Showing of hands ...

MR. STEIN: That is great, 10 percent.

I think you have proved the point.

Do we have any comments or questions?

DR. PRITCHARD: Mr. Chairman, while you were talking, another point occurred to me which I had intended to include, and which I will try to put in, in units without using factors of 10.

There is inherent in my computations a requirement that dilution water be available for the diluting plume, and there is inherent in the Department of Interior "white paper" an assumption that there is some mysterious invisible but impermeable barrier erected vertically at the 100-foot contour, which separates the waters inshore of the 100-foot contour from the rest of the lake volume. I find this assumption to be untenable.

All of the river inflow and all of the undissolved material which enters the lake enters at the shoreline into the inshore area. If, in fact, there was this impermeable barrier separating the waters inside the 100-foot contour from waters offshore from the 100-foot contour, then we should see the water pile up very high along the shore, and also we should see the dissolved components increase without limit in the inshore area.

Now, one can take an estimate of the rate of input of freshwater and the rate of input of dissolved solids and the stated concentrations of the various components of the dissolved solids in the inshore waters and in the open waters of the lake and make a reasonable estimate of the exchange that must occur between the open lake waters and the inshore waters of the lake,as defined by the Department of Interior "white paper."

I have made this computation following a question that was raised at the Illinois hearing, and by my computation I estimate that the rate at which the inshore waters are renewed by waters from the open lake is equivalent to a flow of 1,480,000 cubic feet per second. By comparison, the amount of condenser cooling water that would be required by powerplants rejecting a total of 3.5 times 10 to the 11th B.t.u. per hour at a 20-degree F. temperature rise or rejecting approximately 10 times the amount of heat presently rejected to the surface waters of the lake would be 7,200. That is a comparison between 1,068,000 cubic feet per second, as a rate of supply for new water from the open waters of the lake to the inshore, and a requirement on a part of that many powerplants of 78,200 cubic feet per second. This ratio comes to .053.

MR. STEIN: Thank you. Are there any questions?

You know, I am delighted, Dr. Pritchard, to see that we can translate 10 to the 11th very rapidly to a finite number. You have just done it and that is great.

MR. PURDY: Mr. Stein.

MR. STEIN: Mr. Purdy.

MR. PURDY: Dr. Pritchard, in your calculations, you have used consistently a 20 degree Delta T. Is there a preference on your part for using a 20 degree Delta T, or could you compensate for a lower or a higher Delta T in the design of your outlet structure and accomplish the same thing in the lake?

DR. PRITCHARD: I made use of the 20 degree Delta T since this is a value which is not common, at least representative of the number of powerplants in existence or under design on Lake Michigan. Computations could equally be made if the temperature rise were 10 degrees F. initially. This would involve twice as much water, and hence the discharge structure would have to be designed to take this much larger flow. A lower initial temperature rise would result in lowering the areas contained within some of the higher temperature isotherms providing one kept the width of the discharge this same. This means you would have to -- if you had a temperature, you would have to double the velocity or discharge for such a case, and you would effectively reduce some of the areas within some of the higher temperature -- excess temperature contours near 10 degrees, for example.

This is somewhat obvious, since in this latter case there would be no water higher than 10 degrees. So you wouldn't have any areas 12 or 14 degrees. However, as we get down to 4 degrees or so -- 4 degrees, 2 degrees -- at such temperature, these two cases must come together. That is, they must essentially provide for the same area, because we have the same amount of heat, and in the end when we get far enough away from the point of input the critical thing is the amount of heat rejected and the areas are then relatively independent of the velocity discharge. But the computation can be made, it has been made for other areas, for any temperature rise at the condensers.

MR. STEIN: Mr. Currie.

MR. CURRIE: Dr. Pritchard, most of your paper deals with the physical aspects of heat dissipation and that sort of thing in the lake, and I take it that principally is your training, is it not, physical aspects?

DR. PRITCHARD: Mr. Currie, the field of oceanography is a scientific study of the oceans, its contents both living and dead, and its boundaries from the high tide level to the present physical depths. This means that as an oceanographer I received training in physics, chemistry, biology, and geology of the marine environment. Now, in fact, my training did not include studies of the biology of freshwater bodies. However, as we so eloquently heard yesterday from scientists from Illinois, the basic principles of biology are invariant whatever the medium, and I am familiar with the basic principles of biology that apply to aquatic and marine organisms.

I direct research programs and have biologists under me who carry out research programs dealing with the biology of both aquatic and marine organisms, though my major field of application of my studies is the physics.

MR. CURRIE: Well, the Commonwealth Edison Company, I understand, has additional witnesses who will deal with some of the biological aspects of this as well as yours.

DR. PRITCHARD: That is true.

MR. CURRIE: Now, on some of the physical matters, you say that the area affected by -- that is above 1 degree F. by approximately -- multiplying by 10 times the present power capability along the lake -- would be only .14 percent of the lake's surface, and I believe it is also true that according to the same table that means approximately 20,000 acres, is that correct? This is page 19.

DR. PRITCHARD: That is correct. The 1-degree line would be -- would enclose for -- the total area enclosed by the 1-degree line from all of the plumes from our plants discharging 10 times the amount of heat now discharged to the lake would total 20,000 acres.

MR. CURRIE: So that while we are talking about a small percentage of the total surface, the lake itself is so large that we are talking, in fact, about 20,000 acres.

DR. PRITCHARD: We are talking about 20,000 acres of 1 degree; we are talking about 2,270 acres at 3 degrees.

MR. CURRIE: Yes. Now, you don't deny, do you, Dr. Pritchard, that the degree of mixing between open waters of the lake and inshore waters of the lake may be somewhat inhibited by currents along the shore and by the so-called thermal bar?

DR. PRITCHARD: There will be a number of factors which will both promote and discourage mixing between the open waters of the lake and the inshore waters. I do not consider the thermal bar, however, to be an actual barrier to mixing. If we consider the physics of the phenomenon,

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at the time the so-called thermal bar exists, the lake temperature decreases when it moves offshore and is the highest onshore and decreases to a volume of 39 degrees or approximately 39 degrees F., or approximately 4 degrees centigrade -- that is the temperature of maximum density of freshwater at the point of the thermal bar -- and then slowly continues to decrease as one moves into the main body of the lake. And the waters both offshore, where this water is colder than 39 degrees, and onshore, where this water is warmer than 39 degrees, are less dense than the waters at the thermal bars. The water at the thermal bar must be in active vertical motion. The fact that the temperature increases as one moves shoreward from the thermal bar means that there is lighter water on the shoreward edge of the inshore region, and the denser water offshore, and this gradient produces a slope to the surface with the water near shore standing slightly higher than the water offshore, simply because it takes a greater height of water to equal the same weight if it weighs less.

Now, this slope of the water surface combined with the effects of the earth's rotation produce a current along the shore, and this current will be at maximum in the inshore region and essentially die out at the thermal bar. Now, this means that there is a gradient in velocity, a difference in the speed of the water flowing alongshore inside of the bar and offshore from the bar. Whenever such a shear in the velocity field occurs, the effective lateral diffusivity or the rate at which materials are diffused across a boundary is increased because of the shear. So that the conditions which are associated with the thermal bar must set up a motion, and that motion, because it represents a change in velocity field at the thermal bar, must provide for an actual increase in the transport of material across the bar.

As evidence for this, if the thermal bar really represented a barrier, we would expect to see the dissolved components which have their origin at the shoreline increased during periods of the thermal bar and we do not.

MR. CURRIE: In fact, I take it that you rather sharply disagree with the views expressed by the Department of the Interior in their paper presented on this subject.

DR. PRITCHARD: I do.

MR. CURRIE: And have you conducted any field studies in Lake Michigan to disprove their position?

DR. PRITCHARD: I have not conducted field studies in Lake Michigan. I have studied one of the Great Lakes, Lake Ontario, and the south shore of Lake Ontario between

Rochester and Sodus Bay.

We undertook -- my colleagues and I -- to discharge dye at a location offshore but in the inshore zone and we did this three times during the year. One occurred during the period of the so-called thermal bar, which also develops in that lake as well as in Lake Michigan, and we discharged dye over a 20-day period and looked at the distribution of dye as it spread downcurrent in an easterly direction, as the current flowed in response to the thermal gradient.

Now, we made runs offshore measuring the dye concentration at a number of sections downstream from the point of discharge and observed that the dye concentration decreased sharply when we reached what would be called the thermal bar. The first impression is, while the dye is all contained within this thermal bar and it is some type of a barrier, upon further examination of the data, we realized when we tried to account for continuity of the dye that dye was being lost between successive downstream segments, and that the only way it could be lost would be to be lost out into the open lake where two things happened: one is to essentially be peeled off by the large-scale eddies at the edge of the bar, and because of the shear and the velocity field, and relatively large horizontal diffusion causes a very rapid mixing, so that the concentration of dyes simply drop below the levels of our ability to detect with the gear we had on hand, even though it had been transported through this invisible barrier offshore.

Further, there is an active sinking of the waters at the thermal bar, so that some of the material carried through the bar by this diffusing process were actually sunk below the surface layers where we were measuring the dye. And I am convinced from this field experiment that we have demonstrated the fact that the thermal bar is not a barrier to diffusion of materiel from the inshore waters to the offshore waters.

MR. CURRIE: And you are convinced, Dr. Pritchard, that the conditions were comparable to Lake Michigan conditions when you were conducting this Lake Ontario experiment?

DR. PRITCHARD: I am not.

MR. CURRIE: Well, Mr. Chairman, it seems to me that since Dr. Pritchard's paper so clearly contradicts the findings of the Department of Interior on a very important part of their thesis, it would be helpful to have, at some point, the views of the Department of Interior on Dr. Pritchard's paper, to make the record complete.

MR. STEIN: All right.

The way we generally work that is to put the Government on first and let the other people have the right of rebuttal, but if you want that, and if the industry is consonant, I have no objection to that procedure.

MR. PURDY: I have a couple of other questions.

Was I right, Dr. Pritchard, when I asked the gentleman from Sargent and Lundy this morning -- when I suggested to him that there might be a significant difference between your view and his as to the value of dilution of heat from the thermal plume? Is there a substantial difference? They seemed to be saying that dilution should be minimized and you seem to be saying it should be maximized in order to minimize the adverse effect of heat on the lake.

DR. PRITCHARD: Well, if that is what they said we are evidently in disagreement. I might point out there are several points of agreement first, and we ought to seek these.

We certainly, in all of the studies, have shown that heat is confined primarily to the surface layers. A thesis held by the people -- the people meaning Consumers this morning, and myself, and by all of the students of the distribution of thermal discharges on the lake -- that is, that the excess heat, the temperatures above ambient occur in the surface layers; second, that all of the heat is ultimately lost to the atmosphere. The difference of view concerns whether or not it is desirable to promote a loss of most of the heat from areas having high temperature excess or to -- rather than doing that, my contention is that it is best to reduce the area having high temperature excess as rapidly as possible and allow the temperature to be lost from the atmosphere from relatively large areas of low temperature.

There is no question that if one carried out the kind of analysis that I have done, to look at the areas contained within, say, isotherms of a tenth of a degree F., then the areas contained within isotherms of a tenth of a degree F. would be larger for my approach than for the cooling approach.

MR. PURDY: But your view on that would be that the tenth of a degree is insignificant, would it not?

DR. PRITCHARD: That is correct. I consider that an organism, as has been stated here, does not sense heat. It senses concentration of heat or temperature. The real crux of my argument is contained on page 21, my table 3, which speaks about the time of contact. This is really the time at which a slug of water which passes through the

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condenser is subject to the temperatures, and any organism contained within that slug of water is subject to the temperature rises, given in the left-hand column. One can see that if we take a design which is intended to minimize rapid dilution that organisms contained in the plume would be subjected to temperature rises greater than 10 degrees for 1 hour as compared to 47 seconds for the case of a discharge design to promote mixing -- one being satisfactory -- but there are going to be more organisms in my Case IV than in my Case II, since I've had the entrained dilution water. My point is that if I have no effect by keeping the time small enough, it really just doesn't matter that I have exposed more organisms. And I have conducted experiments; I have been party to the planning and to the analysis and the results of experiments in which organisms, very critical organisms -- they don't happen to be Lake Michigan organisms, but they, as I pointed out, remain the same -- organisms that are highly susceptible to temperature change. For instance, oyster larvae -- the early stages in the development of larvae of oysters in the Chesapeake Bay, at a time when they are microscopic and free swimming and subjected to entrainment through the condenser cooling water system and being passed out into the thermal plume -- and these organisms can be killed -- 50 percent of them killed -- within a 24-hour exposure

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to a 10-degree temperature rise from 83 degrees to 93 degrees.

However, there is no significant difference between control specimens or populations and populations of oyster larvae exposed to temperature rises characteristic of passing through a condenser and, say, a 3-minute exposure on the way out to the discharge point, and then a rate of cooling characteristic of this Case IV. And I am convinced that this is the key biological question: How long are organisms exposed to a given temperature rise? What is the temperature history of organisms entrained into the plume? The problem is that people consider the plume as some sort of stable water mass, and there is a lot of organisms living in there that wander in and become fried when, in fact, this is a dynamic system, always changing. The water is moving through and out, being diluted and cooled, and the organisms are being subjected to this motion, and they are not exposed to temperature rises for a very long period.

This is especially crucial with respect to this question of changes in population. We have had several references to two phenomena that are predicted because of temperature rises in the lake. One of these phenomena has been called eutrophication. I consider that it is a highly misapplied word. For one thing, eutrophication means to me the undesirable presence of an excessive population of microorganisms favored by the environmental conditions; that is a large standing crop -- in general, a standing crop of plants which are unfavorable, as far as food for the grazers. A healthy environment, on the other hand, is an environment in which the plant population is produced at the rate which the grazers use it.

In other words, the cows crop the grass at the daily rate of growth, and this is the most efficient use and it is the way the energy in the biosystem is passed from the primary producers to the secondary producers and on up the food chain which has been recognized as being most healthy. When one has the condition of eutrophication, organisms are favored which are not desired by the grazers and so they tend to grow without limit, and then when they have exhausted the energy supplied by the sun or any other immediate available nutrients, they die off in large masses and cause an undesirable condition. Eutrophication from that sense depends only on the amount of nutrients, not on the temperature.

However, temperature may change the distribution of organisms. It is admitted that if one moves to a lake of higher temperature, one finds a different suite of organisms. The suite of organisms may be undesirable in the environment that you live in. For instance, Lake Michigan.

However, in the cases that I have described, even the existing cases, let alone the well designed cases, organisms will be exposed in the thermal plume to temperatures of significance from the standpoint of population change for such a short period of time -- short compared to their reproductive cycle -- that there will be no change in the distribution of populations. You will not see a shift to blue-green algae, for example. It just cannot occur in these few seconds, 2 minutes, to a few hours. It takes days for such a transfer of a change in the population, and my whole case is really built on this time factor.

MR. STEIN: Mr. Currie.

MR. CURRIE: Yes. Did I gather, Dr. Pritchard, that yesterday when Mr. Barber was on the stand for the Department of Interior, he was disagreeing with your estimates as to the amount of time that a given molecule or organism would remain at a high temperature? I thought he was.

DR. PRITCHARD: Yes, he did.

MR. CURRIE: Do you have anything to say to that point?

DR. PRITCHARD: He made an estimate or used an estimate -- I don't know the origin of that estimate that --

I think it is contained in the "white paper," however -- that the minimum residence time for the heat discharged from a powerplant to the lake would be about 10 days.

Now, there are two points here: One is that I don't think he implied that the thermal plume, as such, would remain for 10 days -- he meant to imply this anyway-- that the thermal plume would remain without change and then suddenly disappear. The second point I would make is that the time changes that I have computed depend both on dilution and cooling, so that when I say that an organism would be exposed or a water particle composed of many molecules would have temperatures greater than 10 degrees for only 47 seconds, I don't mean that we lose half of the heat in a short time. I mean that dilution has decreased the heat concentration or the temperature by that amount in that time.

If one computes the minimum residence time for the heat discharge into the lake in terms of the large-scale processes, the time depends upon the type of discharge structure. But for Lake Michigan, before one can make this kind of calculation -- and the minimum residence time of heat discharged to the lake surface waters in the case of cooling would only be about 2 days, and in the case of complete mixing would be about 4-1/2 days -- but this does not mean that the temperature stays up during that time. The temperature has dropped because of dilution and then there is a slow loss of heat from the large areas.

MR. CURRIE: Thank you.

Again, I think this is one area on which I would like to hear more from the Department of the Interior.

MR. STEIN: Are there any other comments or questions?

MR. PURDY: Mr. Stein, I have one additional question.

MR. STEIN: Yes.

MR. PURDY: Dr. Pritchard, with respect to the -- say, the mortality that might take place through the condenser -- would the Delta T -- would there be a critical Delta T now through the condenser? You are relating experience here with the 20-degree Delta T.

DR. PRITCHARD: I am sure that there would be a combined temperature-time -- critical temperature-time relationship that would have, as a number, to be bound to some maximum temperature rise which organisms could not survive for any time comparable to the time which is necessary to pass them from the condensers to the point of discharge. So that the critical time is really the time to pass from the condensers to the point of discharge coupled with the temperature rise at the condensers, and I am sure there is some maximum temperature rise which would be incompatible with that time, however, small engineering-wise you could make that time. So I am sure that the answer to your question is yes, there is some temperature relationship.

MR. PURDY: You just answered my next question.

MR. STEIN: The advantages of long answers are sometimes they take care of more than one short question.

MR. MAYO: I have got a couple of questions.

As I understand your figure 2, Dr. Pritchard, the isotherms that you show are average for some depth of water, is that correct?

DR. PRITCHARD: They are the upper 10 feet. They represent the temperature at the surface, first of all, and that temperature is assumed to be constant with depth. As I have pointed out in the text, experience has shown that the temperature actually decreases with depth, so that the size of the areas shown in figure 2, while applying to the surface, would actually be larger than the size of the thermal plume at any subsurface depth. So if we take Case IV, for example, and look at the bottom in 10 feet of water, we would find a much smaller area.

MR. MAYO: The point I wanted to get at: Within that area of contact at the bottom an immobile organism or a relatively immobile organism would be continually subject to some change of temperatures that would differ from the period of time in terms of entrainment.

DR. PRITCHARD: Right. Entrainment calculations take care of any organisms carried with the water or free to move into the plume. I might point out that there is ample evidence that fish will avoid an undesirable temperature change, so if they are free to swim they won't move into the plume. But if they are carried into the plume, that is when these times apply. Any benthic organism would be subjected to temperatures in the plume during the time that the plume was extending in their direction. I might point out that these plumes are observed to meander depending on the currents in the open lake, and that the way around this problem is to design the discharge so that the plume never touches the bottom and you do not, then, have any exposure of bottom organisms.

MR. FETTEROLF: Dr. Pritchard, would you care to speculate on what would happen with the Delta T of 28 degrees F. on organisms as they are passed through a condenser and discharged into a canal?

DR. PRITCHARD: You are asking whether I could speculate whether organisms in Lake Michigan which might be entrained into the condenser water are carried through the plant and through some discharge structure would be subjected to mortalities or other inconveniences during the temperature rise in the condensers during discharge. I am afraid I am going to have to pass that to later experts. While I am well aware of basic biological principles, that is a specific question concerning specific organisms here in Lake Michigan, and considering a specific reaction which goes beyond my expertise.

MR. STEIN: Any other comments or questions?

Well, I think this is kind of a late answer to Mr. Currie's earlier question.

Let me call your attention to a statement -- several statements -- and I think I understand what you are saying.

On page 3 of your statement you say, "...it is unlikely that man-induced temperature changes over any significant fraction of the lake surface which fall within these natural fluctuations will have any measurable effect on the ecology of the lake." That refers to Lake Michigan.

Then flip to page 26. You say, "I have investigated the circumstances associated with all mass mortalities of aquatic organisms which have been reported during the last 5 years as being caused by thermal shock, in large lakes, in tidal estuaries, and in coastal waters. In every such case, there is clear evidence that the primary cause of the mortality was not thermal."

Then you go down in the last paragraph and say, "None of these studies have demonstrated adverse effects of the heated discharge on the ecology of the receiving waterway" and you go on to say, "In most cases, a new or augmented sport fishery has been established in the thermal plume ..."

Now, as I read that, these statements go together, and perhaps the Interior report and some of these people are on the wrong track.

If in no cases we have had any adverse effects from thermal pollution and the only effects we have been able to find is to improve the fishery, perhaps the thrust of this operation should be to encourage the discharge of heat into the lake rather than to restrict it. I think we may be on the other side of the moon. What do you think of that, Dr. Pritchard?

DR. PRITCHARD: You have stated it very well.

MR. STEIN: Well, I am glad we understand each other. The issues have never been more clearly drawn. Thank you very much.

I think we had better take a 10-minute recess.

(Short recess.)

MR. STEIN: Let's reconvene.

Mr. Bane.

MR. BANE: Mr. Chairman, responding to your query and to Illinois Chairman Currie's suggestion, I would like to say that we would welcome the comments of the Department of the Interior, the Fish and Wildlife Service, the anonymous authors of the "white paper" on Dr. Pritchard's comments. And, indeed, I believe that if we do not receive or if the conferees do not receive those comments from the Fish and Wildlife Service that then the conferees should take Dr. Pritchard's statements as being accurate and unrefuted.

MR. STEIN: Glad to have your views. I think Dr. Pritchard's statement and your views speak for themselves.

MR. BANE: We have been asked by Commonwealth Edison if we could step aside for 25 or 30 minutes, if that is agreeable with you, Mr. Chairman. There is a Wisconsin witness who has only today available. It is agreeable with us if it is all right with you and the conferees.

MR. STEIN: Pardon me. Let me get off the record a minute.

(Discussion off the record.)

MR. STEIN: Why don't we proceed.

MR. PETERSEN: Thank you, sir.

Mr. Keshishian.

STATEMENT OF PAUL KESHISHIAN, DIRECTOR, POWER PRODUCTION, WISCONSIN POWER AND LIGHT COMPANY, MADISON, WISCONSIN

MR. KESHISHIAN: Mr. Chairman, honored conferees, ladies and gentlemen. My name is Paul Keshishian. I am the Director of Power Production of the Wisconsin Power and Light Company.

Wisconsin Power and Light Company is an investor-owned electric, gas and water utility. It provides retail electric service to 232,000 customers in over 400 communities. It provides wholesale electric service to 33 municipalities and 5 cooperatives. Its service area occupies 15,000 square miles in central and southern Wisconsin with a population of almost 700,000.

Wisconsin Power and Light Company owns and operates four fossil-fueled electric generating plants with a total generating capacity of 780,000 kilowatts. One of the generating plants, Edgewater, with a capacity of 458,000 kilowatts, is located on Lake Michigan at Sheboygan. Two are located in Rock County and one in Grant County. It owns hydroelectric facilities with a generating capacity of 51,200 kilowatts.

Wisconsin Power and Light Company in partnership with Wisconsin Public Service Corporation and Madison Gas and Electric Company is in the process of constructing a 527,000 kilowatt nuclear generating plant on Lake Michigan near Kewaunee in Kewaunee County. Operation of the Kewaunee plant is planned for 1972. The same three companies are also constructing a 527,000 kilowatt fossil-fueled generating plant, known as the Columbia station, near Portage, Columbia County. Commercial operation of the Columbia plant is scheduled for 1975.

Wisconsin Power and Light Company is pleased to have the opportunity to participate in the development of a policy for the responsible use of our water resources. It will be pleased to carry out any policy that provides for a meaningful, workable, realistic solution to the problem of the responsible use of our water resources. It has an interest in the development of such a policy as a responsible citizen of the State of Wisconsin and of the communities in its service area. It has an interest in the development of such a policy as an electric public utility charged with the responsibility under Wisconsin law of not only providing adequate electric service to its customers but also reasonably adequate facilities to enable it to provide that service. Wisconsin Power and Light Company believes that its record to date in all phases of pollution abatement establishes its position as a responsible citizen in these areas.

Wisconsin Power and Light Company supports the efforts to establish a limitation on the temperature of water discharged into Lake Michigan. It must oppose, however, any limitation adopted in the name of environmental protection which in reality imposes an unnecessary and costly burden upon the electric rate-payers without producing a corresponding benefit. It is Wisconsin Power and Light's position that the proposed 1 degree Fahrenheit limitation at the point of discharge is virtually an unattainable goal. Moreover, it is a goal which has little real meaning from the standpoint of environmental protection. Its real and primary effect will be to force utilities to cool water by other means at substantially higher costs to the detriment of the rate-payer.

Wisconsin Power and Light would support a 5 degree Fahrenheit limitation on discharged water if that limitation were coupled with a reasonable mixing zone for measurement purposes. It would also support a requirement that the discharged water be continually monitored and that appropriate corrective action be taken when any harmful effects are shown to exist.

To put the problem in its proper perspective, it would be helpful to examine the actual temperature impact of electric generating units on Lake Michigan. It is anticipated that in the year 2000 with the projected increase in use of electric energy and the corresponding increase in generating facilities, the heat imparted to Lake Michigan by these generating plants is negligible when compared to the heat imparted by solar radiation. Thus, at the January 1968 Four-State FWPCA Lake Michigan Conference, it was stated: "Assuming the powerplants to operate with an average output equal to 80 percent of plant capacity, and assuming no escape of the input heat from the water, the combined effect of the existing plants plus the proposed nuclear plants would not raise the overall water temperature by as much as one-tenth of a degree Fahrenheit. Even this minute increase in water temperature would be nullified during the following winter, so that no progressive warming tendency for Lake Michigan attributable to powerplants is expected to occur."

Going further, our studies have shown that heat given off by all the powerplants in the year 2000 during a 1-year period would be less than .2 percent of the heat generated by the sun on Lake Michigan for the same amount of time.

Measurements taken at existing plants along Lake Michigan including Wisconsin Power and Light Company's Edgewater Plant, show that heat dissipation from a plume is very rapid. The water discharged quickly forms a thin surface layer and there is practically no temperature change a few feet below the surface. Seventy percent to 80 percent of the area covered by this plume of warmer water is from 2 degrees to 5 degrees above the ambient water temperature.

Studies of powerplants throughout the United States but most especially along Lake Michigan including the Edgewater Plant establish that plumes are found to exist only a couple thousand feet out from the point of discharge. The length, of course, varies with wind and current velocity and direction. The same studies have shown that generating plants on Lake Michigan have produced no deleterious effects on benthos and water life of the area. In fact it has been established that discharge waters are beneficial and are being used for incubation areas for water life.

The question of the appropriate temperature limitation for waters discharged into Lake Michigan involves the balancing of the interests of all sectors of the public in the use of Lake Michigan. Wisconsin Power and Light Company submits that a 5 degree Fahrenheit limitation that is coupled with a reasonable mixing zone and constant monitoring of the discharge waters with appropriate remedial action when any actual harm is detected does represent an appropriate balancing of those interests.

Thank you.

MR. STEIN: Thank you.

Are there any comments or questions?

I think we may be beginning to see the light at the end of the generator. Here is the first one that has come up -- why don't you just wait there? -- with a limitation on the other end -- 5 degrees. I would like to emphasize at least the numbers because I am not sure I quite follow it. You say and go along with, "In fact it has been established that discharged wastewaters are beneficial and are being used for incubation areas for water life." If that is so beneficial why do we have to put a limit on that at all? Why did you want to go the 5 degree limitation if you are doing that life so much good by heating the water?

MR. KESHISHIAN: Are you asking the question?

MR. STEIN: Yes.

MR. KESHISHIAN: We are not saying it is

beneficial in all cases. We have said that in many cases around the country utilization of the heated discharge waters have been used to increase trout, game fish productivity. That was the case of the Texas Electric Service area in Texas. Waccamaw Lighting Company at their Northport fossil-fuel station is using heated water to improve the productivity in growth rate of oyster beds. There are a number of other cases in England where they are using heated water to increase productivity.

MR. STEIN: Well, I understand the theory on this, but if the theory is correct that we are doing everyone a benefit by putting in the heated water into the lake then this whole operation, it seems to me, is misdirected. We should encourage you to heat this water as much as possible and put it in. If you are going to heat the lake up, why do we need a limitation of 5 degrees on the top limit? Or why do you want to submit to that 5 degree limitation if you are helping the lake out by heating the water?

MR. KESHISHIAN: Speaking for the Wisconsin Power and Light Company, we are not saying that there can be any unlimited heating of discharged waters in lake bodies; we are saying that in many cases there are beneficial uses of heated water.

MR. STEIN: In other words, you feel that you would go along with not heating the water of Lake Michigan more than 5 degrees from your plant?

MR. KESHISHIAN: We are saying that we feel that a 5-degree limitation, coupled with a reasonable mixing zone and constant monitoring of the discharged waters, with appropriate remedial action when any actual harm is detected, does represent an appropriate balance in those interests.

MR. STEIN: One specific question.

With your plant near Kewaunee in Kewaunee County -- a nuclear generating plant -- if you had that 5-degree limitation, would you have to put up cooling towers, or how would you cool it, once-through?

MR. KESHISHIAN: The Kewaunee nuclear power station is being built under the auspices of three companies: Wisconsin Public Service, Madison Gas and Electric, Wisconsin Power and Light Company. And I would rather defer the answer to the Wisconsin Public Service Company.

MR. STEIN: In other words, you don't know what kind of cooling devices they are going to use?

MR. KESHISHIAN: No, sir, I certainly do know what kind of cooling devices are contemplated for Kewaunee. You asked the question in the event to accommodate the 5-degree limitation what would be necessary -- whether cooling towers would be necessary. I think they should answer that question.

MR. STEIN: Well, again, you know, I don't want to put anyone on the spot here and this is in deference to Commonwealth Edison. But, I think the essence of this operation indicates an additional expense. If you are going to put in cooling towers or other devices and if you can talk about 5 degrees and get by without putting anything in, and Commonwealth Edison cannot do it without putting in some extensive devices, then one can understand why one company talks in terms of 5 degrees and the other company doesn't mention any degrees. I think the key point in the statement here on your 5-degree rise is what kind of devices are you going to have to put in that nuclear plant in order to meet that -degree operation. If that means you don't put any other cooling devices in except that once-through, that may have some significance.

Are there any further questions or comments?

Yes.

MR. MACKIE: Yes, Mr. Stein.

Since a specific suggestion has been made here, a specific recommendation, I assume that we will get a copy of the studies that were referred to. In particular, I am wondering if they are specific to Lake Michigan.

MR. KESHISHIAN: Yes, it is specific to Lake Michigan.

MR. MACKIE: Will the conferees be furnished with a copy of the studies about Lake Michigan?

MR. KESHISHIAN: Yes, sir.

MR. STEIN: When can we have them?

MR. KESHISHIAN: I think we can have them delivered within a week.

MR. STEIN: This week or next?

MR. KESHISHIAN: Next week.

MR. STEIN: All right.

Any further questions or comments?

If not, thank you very much, sir.

Mr. Bane.

MR. PETERSEN: Mr. Keshishian, just a moment. Inasmuch as this witness is leaving, if there were going to be any questions from the floor --

MR. STEIN: Oh, yes. I think that would be the point. Are there any questions from the public of Mr. Keshishian?

MR. PETERSEN: And being at the microphone, I have a question, and the question I have: When you spoke of 5 degrees, Mr. Keshishian, did you speak of 5-degrees

Wisconsin Power & Light Company
Investor-owned Energy
122 West Washington Avenue P.O. Box 192 Madison, Wisconsin 53701 Phone 608/256-3151

October 6, 1970

Mr. Murray Stein
Conference Chairman
United States Department of the Interior
Federal Water Pollution Control Administration
Washington, D. C. 20242

Dear Mr. Stein:

At the recent Federal-State Enforcement Conference on Pollution of Lake Michigan, Wisconsin Power and Light Company gave testimony in regard to plume dissipation. During the questioning you asked if there was available information as to the plume configurations of existing plants. In this regard we are sending to you three isometric graphs depicting plumes from the Edgewater fossil fuel plant of Wisconsin Power and Light Company, the Big Rock Point Nuclear Plant and J. H. Campbell fossil fuel plant, both of Consumers Power Company.

We are sure the information contained will demonstrate the quick dissipation of heat within the plume.

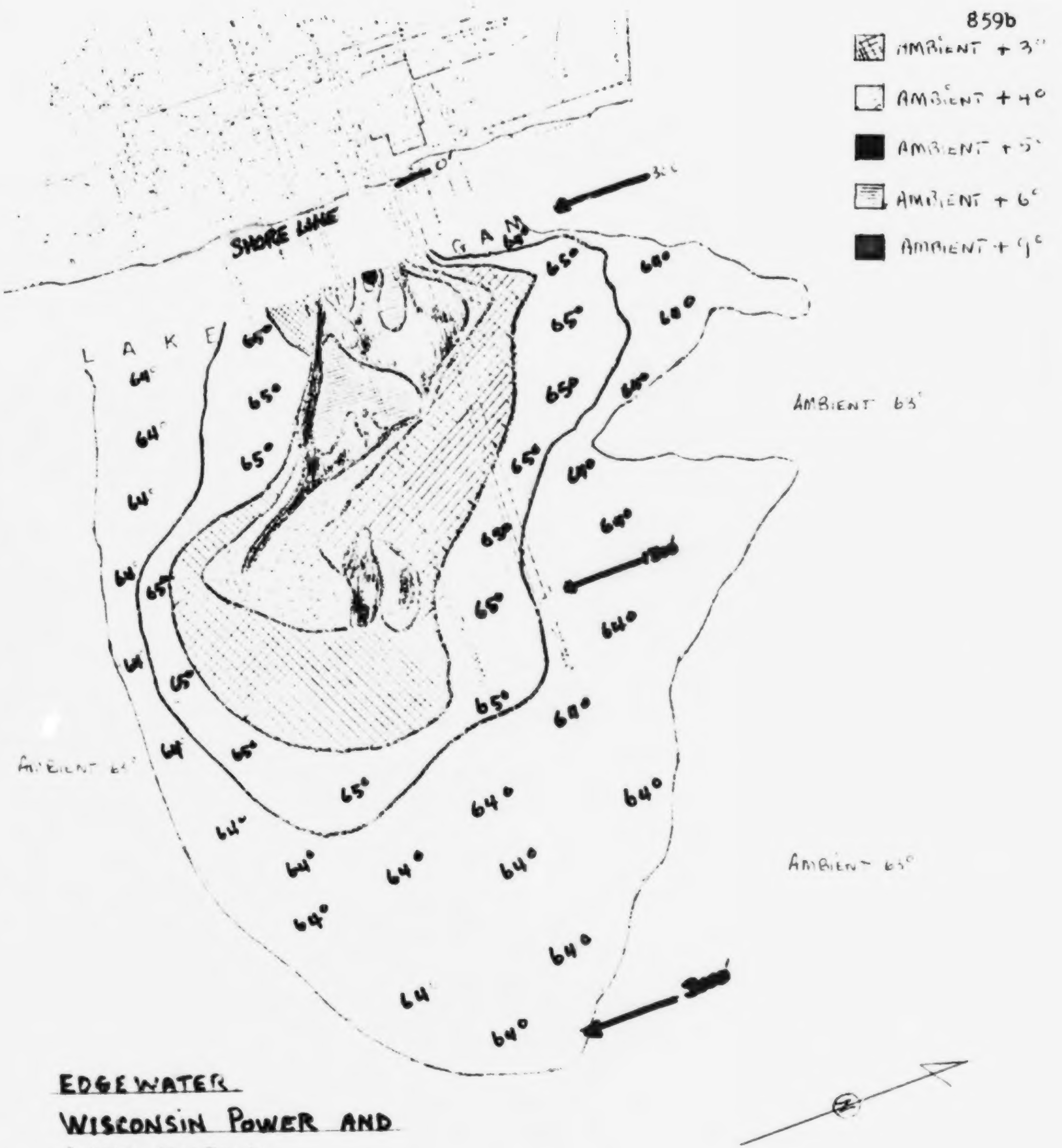
Very truly yours,

Paul Keshishian

Paul Keshishian
Director of
Power Production

PK:rb

Attachment


859b
▨ Ambient + 3°
☐ Ambient + 4°
■ Ambient + 5°
▤ Ambient + 6°
■ Ambient + 9°
Shore Line
Lake Michigan
300'
1500'
3000'
Ambient 63°
Ambient 63°
Ambient 63°
64°
65°
64°
65°

EDGEWATER

WISCONSIN POWER AND LIGHT COMPANY

8-25-70

WIND FROM S. 7-10 M.P.H.

CAPACITY 458,000 K.W.

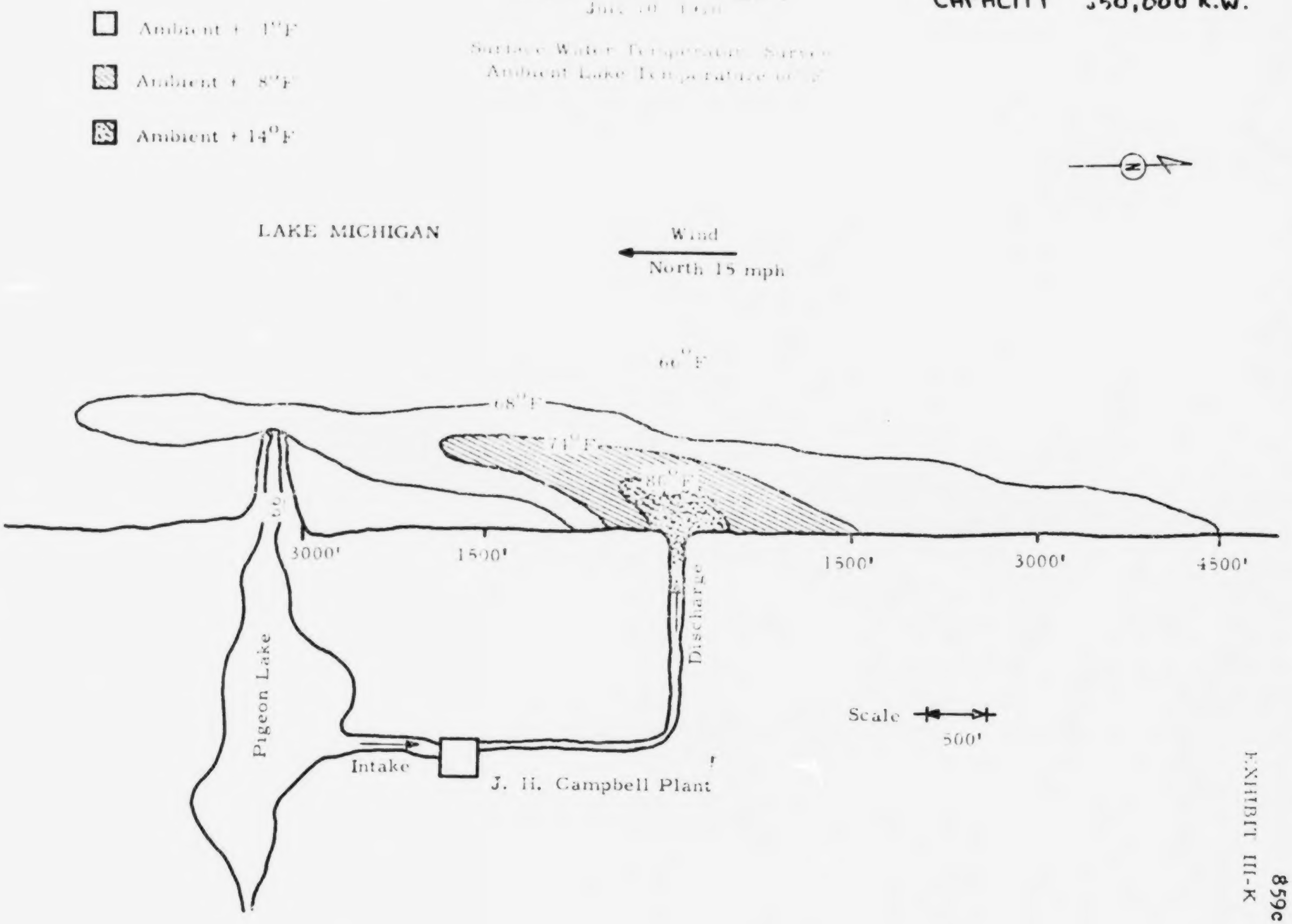
AMBIENT 63°

EXHIBIT III-K

CAPACITY 350,000 K.W.

J. H. CAMPBELL PLANT
July 10, 19[illegible]

Surface Water Temperature Survey
Ambient Lake Temperature 60°F


☐ Ambient + 1°F
▨ Ambient + 8°F
▩ Ambient + 14°F
N
LAKE MICHIGAN
Wind
North 15 mph
60°F
68°F
71°F
80°F
3000'
1500'
1500'
3000'
4500'
Discharge
Scale
500'
Pigeon Lake
Intake
J. H. Campbell Plant

CAPACITY 7' 100 K.W.

BIG ROCK POINT NUCLEAR PLANT
June 18, 1968

Surface Temperatures
Ambient 52°F

Wind S 5-10 Mph

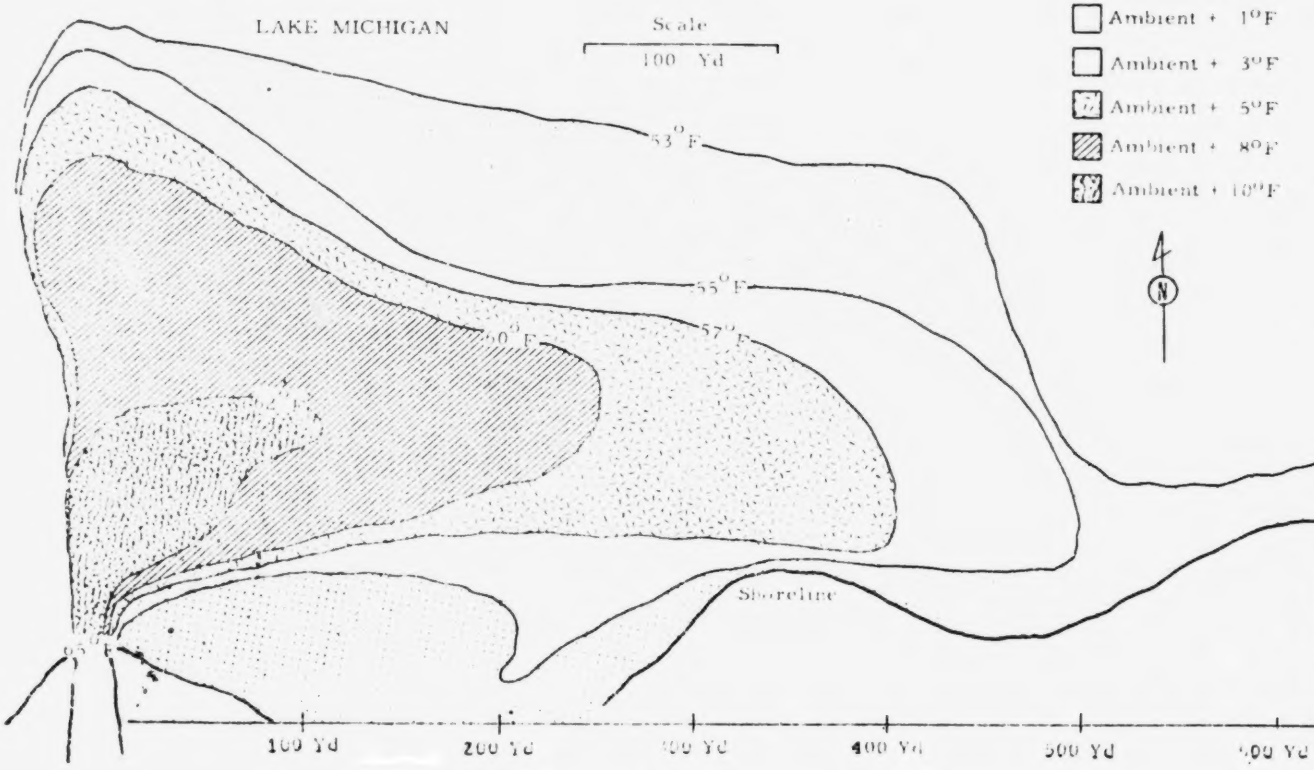

LAKE MICHIGAN
Scale
100 Yd
☐ Ambient + 1°F
☐ Ambient + 3°F
▨ Ambient + 5°F
▨ Ambient + 8°F
▨ Ambient + 10°F
N
53°F
55°F
57°F
60°F
65°F
Shoreline
100 Yd
200 Yd
300 Yd
400 Yd
500 Yd
600 Yd

EXHIBIT III-E

temperature rise or 5 degrees at the edge of the mixing zone?

MR. KESHISHIAN: We are speaking of 5 degrees Fahrenheit at the edge of the mixing zone. I think the statement is pretty clear. It says the "Wisconsin Power and Light Company submits that a 5 degree Fahrenheit limitation that is coupled with a reasonable mixing zone and constant monitoring of the discharge waters with appropriate remedial action when any actual harm is detected does represent an appropriate balancing of those interests."

We are saying the edge of the mixing zone; we are not saying the point of discharge of the pipe.

MR. STEIN: Any other comments or questions?

Thank you, sir.

MR. BANE: Mr. Chairman, resuming with Commonwealth Edison Company, our next three witnesses are going to give testimony that is somewhat interrelated. Dr. Lee is going to talk about chemical effects, and the two following witnesses are going to discuss the biota and the effects of heat on them.

I would like to suggest, if it is agreeable, that all three might give their direct testimony and then we would submit them as a panel to the panel -- to the conferees for examination.

MR. STEIN: Let me suggest, to do this with the conferees -- we have been through this before, and I think this is so complicated that for the purposes of the record I would hope that we could keep the questions and the answers short. But I think -- let's take them up one at a time to get into the issues.

MR. BANE: Yes. All right, sir.

MR. STEIN: I think in the long run, Mr. Bane, this will save time.

MR. BANE: That is all right.

One other point, Mr. Chairman, I would like to mention at this time.

After the next three, we would then have two witnesses to complete our case: Dr. Pipes to come back to talk about standards, and Mr. Butler to discuss cooling towers and cooling systems. It would be most helpful to us if we could finish today, and as we are going I think that I could predict that we would finish if the conferees would be willing to extend this hearing today until something like 5:30 or so.

MR. STEIN: Let's make a judgment on that when we get to the time. Looking at the statements, unless they are summarized -- or maybe they will be --

MR. BANE: There will be some summarization, yes.

MR. STEIN: Mr. Bane, let me tell you this: Personally I think if we can finish at 5:30 I would certainly be for it. But I think before we make a judgment on that, let's see where we are and see if we are actually going to hit 5:30.

MR. BANE: All right, sir. Fine. Okay. Dr. Lee.

STATEMENT OF G. FRED LEE, PROFESSOR OF WATER CHEMISTRY, UNIVERSITY OF WISCONSIN, MADISON, WISCONSIN

DR. LEE: Thank you, Mr. Bane.

Mr. Chairman, conferees, ladies and gentlemen. My name is G. Fred Lee. I hold the position of Professor of Water Chemistry at the University of Wisconsin. I have a Bachelor's Degree from San Jose State College. I have a Master of Science in Public Health from the University of North Carolina. I have a Ph.D. from Harvard University with a major in Water Chemistry and with minors in Aquatic Microbiology, Limnology, and Sanitary Engineering.

My primary areas of activity are in the areas of teaching and research in water chemistry.

By water chemistry we mean the chemistry of natural waters, water and wastewater treatment, and water pollution control. I am primarily concerned with what happens to pollutant chemicals in natural waters and the factors influencing the concentrations and forms of chemicals in natural waters.

I am also concerned with the interactions of various chemical pollutants and aquatic organisms, and effects of chemical pollutants on water quality.

An area of my specialization is the eutrophication of natural waters with emphasis on the causes, effects, and methods of control of eutrophication.

I am an advisor to governmental agencies and industrial firms including the President's Council on the Environmental Quality in the area of eutrophication and chemical pollution of water.

I am consultant to the Commonwealth Edison Company, assisting them in evaluating the effects of their Waukegan and Zion discharges on water quality in Lake Michigan. I have been asked by Commonwealth to discuss the effects of thermal discharges on the chemical paramaters of water quality and on eutrophication.

A manuscript covering this topic has been distributed. I will summarize the highlights of it and comment on certain sections of the U. S. Department of

Interior Fish and Wildlife Service "white paper" on the effects of thermal discharges on water quality.

MR. STEIN: Without objection, Dr. Lee, your full statement will be included in the record as if read.

DR. LEE: Thank you.

(The document above referred to follows in its entirety.)

Effect of Thermal Discharges on the Chemical Parameters of Water Quality and Eutrophication

by

G. Fred Lee

Professor of Water Chemistry

University of Wisconsin
Madison, Wisconsin

Introduction

One of the areas of primary concern today is the effect of thermal discharges to surface waters on the chemical parameters of water quality. Of particular concern in lakes is the effect of heated discharges on the degree of eutrophication of the receiving water. This paper summarizes the current state of knowledge in the area of the relationships between thermal discharges and the chemical characteristics of the receiving water.

In order to understand the effect of temperature on the chemical parameters of water quality, it is necessary to have some estimate of the amount of temperature increase that will likely be encountered, as well as the time during which the elevated temperatures will be present.

Considerable confusion exists today on the amount of heating that will actually take place in a large lake like Lake Michigan from the installation of large nuclear electric generating stations. It is true that large amounts of heat must be dissipated from such installations and that location of such installations on small bodies of water, or in situations where a significant part of a river flow will be heated, could lead to water quality problems. However, the location of such electric generating stations on lakes like Lake Michigan will have only a localized heating effect on the lake. The area and volume of the lake that will be affected by a significant rise in temperature from nuclear electric generating stations, such as Zion, is not significant compared to the total area or volume of Lake Michigan. In fact, the installation of many electric generating stations such as Zion will not cause a measurable increase in the overall temperature of the lake.

Examination of the thermal plume characteristics of existing electric generating stations, such as the Commonwealth-Edison Waukegan station and the predicted characteristics of plumes from Zion Station shows that, in general, there will be a ten to twenty degrees increase in the temperature of the water at the point of discharge.

Actually, for some of the newer discharge works, such as that at Zion, the excess temperatures in the order of 5°F above ambient, or greater, persist for less than ten minutes. From an overall point of view, this highly localized rapid heating and cooling results in little or no effect on the normal chemical parameters of water quality.

In order to understand the role of heated discharges on chemical parameters of water quality, one must consider the path of a pollutant molecule, piece of particulate matter, etc. as it goes through the period of elevated temperature. As this molecule of particulate matter enters the intake works it is subjected to a greatly increased velocity and shear and passes through the condensers of the electric generating station where there is a rapid rise in temperature in the order of 10 to 20°F. Dependent on the design of the discharge, the elevated temperatures will persist for several minutes and upon exposure to the lake water and the atmosphere the chemical pollutant is then rapidly cooled in the matter of a few minutes to a few hours , to its original ambient condition.

With this information as background to our discussion, it is appropriate to consider the various types of chemical reactions that may occur in natural waters and how these reactions might influence water quality.

General Considerations.

Many of the chemical reactions that occur in natural waters show an activation energy in the order of 15,000 Kcal per mole. An activation energy of this order of magnitude is equivalent to a doubling in the rate of reaction for each 10°C increase in temperature. Therefore, as a pollutant molecule passes through the electric generating station, there is an opportunity, prior to the time that it cools back to ambient conditions in the lake, for an increase in the rate of chemical reactions. The fact that most chemical reactions are hastened at increased temperatures will not, however, result in a significant effect on the chemical parameters of water quality except in those situations where large amounts of chemical pollution of the waters have recently occurred or where two water masses of distinctly different chemical characteristics are mixed just prior to entering the intake works of the electric generating station. In other words, for most natural waters, the rate of change in the chemical parameters of water quality is sufficiently slow, compared to the excess temperature-time relationship normally associated with the thermal plume, so that no significant change in the chemical parameters of the water occurs.

I should also point out that most of the chemical-biochemical transformations that occur in natural waters tend toward the production of the water with more desirable water quality characteristics. Therefore, any hastening of the normal rates of self-purification would result in improved water quality rather than its deterioration.

Specific Reactions.

The most frequently cited example of an increase in temperature leading to deterioration in water quality is that associated with the removal of biochemical oxygen demand from surface waters. Micro-organisms, in using organic matter as a source of energy, utilize the oxygen in the surface water as part of the respiratory processes. In general, the rates of these reactions increase with increasing temperature. It is conceivable that a body of water with a certain waste load would have adequate amounts of oxygen to maintain desirable fish life at one temperature, while at an elevated temperature, the rate and exertion of the BOD would be increased sufficiently to cause a critical depletion in the dissolved oxygen concentration. Such a situation would occur, however, only if two other conditions are also present: the intake waters of the electric generating station must be grossly polluted, i.e., where large amounts of untreated municipal and/or industrial wastes are discharged immediately adjacent to the intake works, and the elevated temperatures must persist for periods of many hours to days. This type of situation would not be encountered in the majority of the electric generating stations located on large lakes like Lake Michigan and is certainly not the situation that is encountered at the Waukegan and Zion installations of Commonwealth Edison. Here the BOD of the water is in the order of only 1 to 3 mg/l. Increasing the temperature of the water a few degrees will not cause a significant depletion in the dissolved oxygen of the water as a result of increased BOD exertion. This situation is a good example of why it is necessary to consider each individual electric generating station with regard to its potential water quality problems.

The other most frequently cited example of a deleterious effect of thermal discharges on the chemical parameters of water quality is the reduction in the amounts of dissolved oxygen that can be present in the heated discharge waters. To the extent that oxygen and other dissolved gases show an inverse relationship between the solubility of the gas in the water and the temperature of the water, increased temperatures would result in decreased solubility. Since oxygen is an extremely important parameter of water quality, increasing the temperature of the water could cause a deterioration in water quality.

However, it is important once again to examine the actual situation that will likely be encountered in the thermal discharges from a large generating station. Normally, we expect to find that the waters taken into the intake works of an electric generating station from Lake Michigan would be at or near saturation with respect to dissolved oxygen. As the water passes through the condenser it will become supersaturated. As this water is discharged to the plume, there will be a tendency for this supersaturation of dissolved oxygen to be lost to the atmosphere. Actually, the amount of loss that will occur is highly dependent upon the turbulence level that occurs in the discharge plume. With low velocity discharges, i.e., low turbulence, there will be a strong tendency to maintain the supersaturation that developed as a result of the temperature increase in the water. At high degrees of turbulence there will be a more rapid equilibration between the elevated temperature water and the atmosphere. With a high velocity discharge, however, large amounts of water become entrained in the plume. Any depletion in dissolved oxygen due to exchange with the atmosphere is rapidly made up from the surrounding waters. Moreover, in a high velocity discharge, undersaturated waters in the plume tend to equilibrate with the atmosphere more rapidly because of the higher turbulence levels in the plume and thereby regain the lost dissolved oxygen. The overall result normally is a barely perceptible decrease in the dissolved oxygen levels in the plume as compared to those of the surrounding waters.

Therefore, for normal situations where the intake waters do not contain large amounts of oxygen demand pollution material, or are already at critically low oxygen levels, the effect of using the water for cooling purposes probably would have little or no effect on the amount of dissolved oxygen in the water.

Miscellaneous Chemical Parameters.

Tastes and Odors. The taste and odor characteristics of natural waters are often intensified at elevated temperatures. Therefore, the increase in the temperature of the water could cause a deterioration of water quality. However, if we again consider the typical situation that will occur in the Lake Michigan, we will find that it is highly unlikely that water supply intakes would be located immediately adjacent to the discharge works of large electric generating stations. Unless the water, when it reaches the water supply intake, has been raised more than 2°, there would be no significant deterioration in water quality as a result of tastes and odors in the water. Increasing the temperature of water as it passes through an electric generating station and in the plume of the station's discharge in the order of a few degrees would not be normally expected to change the color, turbidity, alkalinity, ammonia, various toxic metals and non-metals, aquatic plant nutrients such as nitrogen and phosphorus, and organic compounds to a degree such that there would be a measurable deterioration in water quality.

Toxicity.

As explained above, the chemical species present in the intake water would not be expected to change as a result of heating the water a few degrees above ambient for a period of a few hours. Therefore, any toxicity problems in the water that would be detected in the discharge plume would not be of a greater magnitude or equal significance than was true in the intake waters.

Eutrophication.

Eutrophication of natural waters is a process of increasing the nutrient flux to the body of water. It results in increased aquatic plant growth with a concomitant decrease in water quality. Eutrophication is one of the most significant problems that occurs in lakes. The nearshore areas of southern Lake Michigan are experiencing significant degrees of eutrophication as a result of the discharge of municipal and industrial wastes as well as runoff from urban and from agricultural areas and natural sources. In addition, precipitation and dustfall from the atmosphere may add significant amounts of aquatic plant nutrients to some bodies of water. Anything that would tend to increase the degree of eutrophication or the problems that are caused by it represents a significant deterioration of water quality. It is generally believed that there is a high degree of correlation between the temperature of the water and the growth of aquatic plants in the water. While there is a correlation between these two, for many bodies of water it should not be taken that higher temperatures cause a greater degree of eutrophication.

There is little doubt that algae and other aquatic plants grow at a more rapid rate as the temperature of the water is increased. However, this does not mean that the total biomass, i.e., amount of algae present in the water, will be increased as a result of the increased temperature. The total amount of algae and other aquatic plants present in a given body of water is primarily dependent on the availability of aquatic plant nutrients, rather than on temperature. Some of the most productive areas of the world's oceans are the cold waters in the Antarctic and the upwelling areas of cold water from deep within the ocean while many of the tropical waters are sparsely populated with aquatic organisms. The differences are primarily due to the rate of nutrient supply and have little or no relationship to the temperature of the water. Therefore, unless it can be shown that heating water for a short time, a few degrees above ambient, would increase the nutrient availability within the water, there is no reason to believe that thermal discharges will have any effect on the degree of eutrophication of a given body of water.

While it is true that the rates of mineralization of nitrogen and phosphorus compounds from dead algae and other aquatic organisms increase with increasing temperature, it will be generally found that the time-temperature relationship that will exist in the normal thermal discharge plume of large electric generating stations located on large lakes will be such as to not alter to any measurable degree the rate of remineralization of nitrogen and phosphorus compounds in the lake water. In other words, the increase in temperature and the relatively short period of time over which this increase takes place is far too short to be of any significance compared to the normal rates of mineralization of nitrogen and phosphorus compounds.

Special consideration must be given to the growth of attached algae in the region of the discharge plume since some forms of these algae, especially Cladophora, do cause a significant deterioration of water quality, especially in southern Lake Michigan. At the present time, the factors that influence the growth of Cladophora are poorly understood. However, it is clear that there are many other factors than temperature which tend to control its growth. Based on the limited knowledge available, it is reasonable to predict that if a suitable substrate for the attachment of Cladophora occurred in the region of the discharge plume, Cladophora would be present at a slightly earlier date each spring as a result of heating the water in the order of a few degrees above ambient. This would occur only in the region of the discharge plume. This does not mean that there would be increased amounts of Cladophora occurring within the lake or within the discharge plume, it means only that they would occur slightly earlier in the spring. This, in my opinion, does not represent a significant effect on water quality since the amount of increased growth that would occur at a few degrees above ambient would be barely perceptible and the area over which such growth would occur would be completely insignificant.

There is one effect that thermal discharges might have which would tend to reduce nutrient availability within the lake. This is the possibility of precipitating calcium carbonate in the thermal plume. Calcium carbonate has an inverse relationship between solubility and temperature. Precipitation of calcium carbonate may, therefore, occur in the discharge plume. If precipitation does occur, it would tend to remove some aquatic plant nutrients, such as phosphorus and various trace elements, and carry these materials to the sediments. However, once again, because of the limited area of the thermal discharge plume,the small temperature increase and the fact that calcium carbonate tends to readily form stable supersaturated solutions, I would not expect any significant effect on the amounts of aquatic plant nutrients in the water as a result of calcium carbonate precipitation.

The other often cited effect that could be caused by thermal discharge is a change in the type of algae present in a given lake. Normally, the secession of algae proceeds from diatoms to green to blue-green algae as the water is warmed in the spring and summer. It is generally believed that the blue-green algae has a preference for warmer waters. Since blue-green algae often cause a greater deterioration in water quality than diatoms or green algae, any factors that would tend to promote the presence of blue-green algae would represent a potentially significant deterioration of water quality. However, the factors influencing the seccession of the various types of algae are not well understood. While it is generally found that blue-green algae are dominant during the warmer summer months, they are not restricted to this period and, in fact, some of the highest concentrations ever encountered by the author have been found under the ice in winter.

If we accept the fact that blue-green algae would be more dominant under warmer conditions, then we must ask if the conditions that are likely to be encountered in the thermal discharge tend to promote the growth of blue-green algae. And here the answer is that the few degrees rise in temperature that will

persist over a period of a few hours will not have a significant effect on the rate of growth, nor the numbers, of blue-green algae in Lake Michigan water. The primary reason for this statement is that planktonic algae normally grow at a very slow rate compared to the time that they will be present in the discharge plume. Algae normally requires several days to double in number. There is no evidence to show that an increase in temperature in the order of a few degrees will significantly alter the rate of growth of this type of algae.

Reversability of thermal effects.

While all available evidence points to the fact that the discharge of heated effluent from electric generating stations located on Lake Michigan, as currently contemplated, will not have a significant deleterious effect on water quality, it is not possible to be absolutely certain that no effects will be encountered. It is important to consider whether the discharge in a heated effluent to Lake Michigan could cause irreversible damage to the lake if, at some future date, some very subtle effects of the heated discharge are found on some types of aquatic organisms. It can be unequivocably stated that thermal discharges, unlike other discharges, do not leave a residue in the water which must be flushed from the lake upon termination of the input. The thermal discharges continuously equilibrate with the atmosphere, there are no long term effects on water quality after the discharge is stopped.

If it is found at some time in the future that a certain type of aquatic organism is significantly effected by thermal discharges, and it is decided that this effect is of such proportions as to warrant the termination of further thermal discharges to the lake, it is reasonable to expect that upon termination of these discharges the affected aquatic organism will recover and repopulate the affected area with normal organisms. In other words, thermal discharges are the only types of discharge to natural waters which are reversible in terms of their effects on water quality.

G. F. Lee

DR. LEE: I wish to start my discussion by saying that there is no doubt that electric generating station thermal discharges can cause water quality problems. Large thermal discharges to small rivers or to small lakes will be detrimental and also if large electric generating stations are placed completely around Lake Michigan so that discharge plumes overlap, there will be water quality problems.

However, a large lake like Lake Michigan has a certain amount of assimilative capacity for waste heat without having a deleterious effect on water quality.

I feel it is a significant waste of the financial resources of the States bordering Lake Michigan to force the public to pay for cooling towers or other devices in order to meet some arbitrary thermal standard that does not take into account the heat assimilative capacity of Lake Michigan.

The best way, I feel, to determine the number of thermal discharges that can be made to Lake Michigan without causing significant deterioration of water quality and to properly utilize the heat assimilative capacity of the lake is to examine the discharge characteristics and the effects of a few electric generating plants and then extrapolate to many plants.

G. F. Lee

If we understand how one plant or a few plants affect a lake, we can begin to understand what may happen when many electric generating stations are placed on the lake. With this in mind, I will restrict my discussions today to a review of the thermal discharges similar to the Commonwealth Edison Zion Plant.

As we have heard from Dr. Pritchard, this plant discharges water at about 20 degrees Fahrenheit above ambient in large quantities to the near shore environment of Lake Michigan. The design of the discharge works for this plant enables a very rapid cooling of the water primarily by dilution so that it will be a few degrees above ambient within a few minutes after discharge and back to essentially ambient conditions within a few hours.

The important question is: Given these conditions, could the heated discharge from Zion cause significant deterioration in the chemical water quality and/or accelerate the eutrophication of Lake Michigan?

I wish to point out that although thermal discharges are alleged to have significant deleterious effects on many chemical characteristics of natural waters, very few studies have actually been conducted in this area.

Fortunately, we are not in as bad a shape as it may seem since we do know something about the aqueous environmental chemistry of various pollutants in natural waters. From this information we can draw inference about the effects of thermal discharges in natural waters.

Temperature affects both the position of equilibrium and the rate at which equilibrium is attained for each chemical reaction.

Even though we do not know the equilibrium and rate constants for many of the chemical reactions that occur in natural waters, we do have a reasonably good idea of how temperature affects both the position of equilibrium and the rate at which it is attained for chemical and biochemical reaction in general. From this information and the time-temperature relationship of a thermal discharge plume from an electric generating station, we can predict with a reasonable degree of reliability the effect that heat might have on certain chemical processes and also estimate how this might influence the growth of certain organisms.

In making predictions in this area, it is necessary to consider the relative rates at which chemical processes proceed in natural waters versus the time-temperature relationship in the discharge plume.

If a reaction proceeds so that only a small part of it takes place each day then heating the water a few degrees above ambient for a few hours will not result in any significant change in the amount of reaction that takes place from an overall point of view.

Most chemical reactions double in rate for each 10 degrees centigrade increase in temperature so that a couple of degrees above ambient does not represent a significant increase in the reaction rate.

Also since my reactions proceed toward a natural purification, the discharge of hot water may actually enhance water quality under certain conditions from a chemical point of view.

In my review of the potential effects of the Zion discharge on the chemical parameters of water quality, I have considered for each of the common chemical pollutants whether or not an increase in temperatures in the order of a few degrees above ambient could result in a deterioration of water quality.

I have concluded, as a result of this review, that based on the time-temperature relationship of the Zion discharge and the chemical and biological characteristics of the water near Zion, no significant deleterious effect on water quality would occur as a result of this discharge.

This review includes such parameters as oxygen, color, turbidity, pH, alkalinity, nitrate, ammonia, phosphate, taste and odors, iron, manganese, copper, zinc, BOD, pesticides, toxic metals and nonmetals, sulfate, rate of release of nitrogen and phosphorus from lake sediments, etc.

This conclusion is based on the fact that the rate at which these various chemical parameters change with a small change in temperature for the Zion water as compared to the time-temperature relationship for the Zion plume is too small to be of any significance in affecting water quality from either a beneficial or adverse point of view.

I wish to mention that while the toxicity of many metals and other chemicals increases with increasing temperature, it has been recently found that DDT, unlike other pesticides, is more toxic to fish at lower temperature than at higher temperatures. Therefore, we must be cautious about making broad generalizations about the deleterious effects of heated discharges.

In the U. S. Department of Interior "white paper," mention is made on page 74 that increased temperature will increase numbers of botulism organisms in lake water. Since this organism causes losses of water birds and is a potential hazard to humans, increased numbers could be of significance. Several of my colleagues at the

University of Wisconsin have been actively investigating the factors influencing the numbers of botulism organisms in Great Lakes waters. I have discussed the "white paper" statement on botulism with them and conclude that the current state of knowledge on the factors influencing the numbers of botulism organisms is such that it is impossible to predict the effect of temperature on their numbers in natural waters.

It has not been established whether or not these organisms even grow in natural waters. Some feel that since they are found in soil in large numbers that the botulism found in water is washed in from the soil. Even if they are found to reproduce in water, increasing the temperature will not necessarily increase numbers of botulism organisms. It is conceivable that the competitors of botulism would be enhanced to a greater degree than the botulism organism with the result that increased temperature would result in lower numbers of these organisms.

The key point I wish to make here is that the positive unqualified statement made in the U. S. Department of Interior "white paper" that numbers of botulism organisms will increase with increasing temperature is not in accord with the best technical information available today.

A similar problem exists on page 76 of the "white paper" where the statement is made that the supersaturation of the dissolved gases that will occur in thermal discharges will cause embolism or bends in fish. While supersaturation of dissolved gases does cause embolism in fish, it should be mentioned that the degree of supersaturation that will occur in most thermal discharges is equal to or less than the amount of supersaturation that is frequently found in the near shore environment of many lakes and streams. Therefore, I doubt that the supersaturation that will exist from that thermal discharge like the Zion plant would cause any increase in the embolism in fish.

Eutrophication is the fertilization of a water that results in excessive growths of algae and other aquatic plants. It is of great significance in Lake Michigan. Already we have excessive planktonic and attached algal growths, particularly the Cladophora.

There is considerable confusion today about what controls the rate and degree of eutrophication in a body of water. Many individuals, including the authors of the U. S. Department of Interior "white paper" have confused the fact that because many algae tend to grow more rapidly at higher temperatures, that there would be increased eutrophication at higher temperatures. This concept is in general incorrect. On page 81 of the U. S. Department of Interior "white paper," the statement is made that nutrients and/or temperature will increase eutrophication. In my opinion, this statement is incorrect as far as temperature is concerned.

The ultimate total population or biomass of algae is dependent on aquatic plant nutrients, not temperature. The effects of algae on man are related to total numbers, not their rate of growth.

The algal population in Lake Michigan are nutrient-limited not temperature-limited. The frequency and severity of obnoxious algal blooms and growth of attached algae in Lake Michigan will not increase because of increased temperature. They will increase if you add additional aquatic plant nutrients such as nitrogen, phosphorus, silicon, etc.

Blue-green algae are usually associated with warmer waters. This emperical correlation is often cited as evidence that thermal discharge will increase blue-green algae. The factors that control the presence or absence of blue-green algae are very poorly understood. Temperature may influence the rate of growth of some blue-green algae. It is certainly not a dominant factor in controlling the biomass present during the summer months. The nutrient levels and other poorly defined factors within a lake control total numbers of blue-greens. In my opinion, no increase in the number of blue-green algae will occur if a water is heated from 20 degrees to, say, 25 or to 30 degrees centigrade.

Let's consider the Zion discharge and its effect on algae. First, planktonic algae grow at a relatively slow rate. A day to several days is needed to double in numbers. There will not be an increase in the numbers of algae present in the Zion plume because of the increased temperature. The time-temperature relationship in this plume is such that there is insufficient time to allow the algae to grow to any degree.

The attached algae such as Cladophora must have suitable substrate for attachment in order to grow. If a suitable substrate is present in the discharge plume area, then we might find that Cladophora would be present a little earlier each spring because of the warmer water. However, we would not expect to find larger numbers of Cladophora in the critical summer months. During the summer, the total biomass of Cladophora is dependent on nutrients and other factors but not temperature.

I advocate a much more liberal approach to the setting of thermal standards more in line with the existing State standards than either the 1 degree Fahrenheit proposed by a former Department of Interior official or the eseentially no heat addition proposed by the U. S. Department of Interior "white paper." I feel that strict thermal standards such as these are not in the best interests of the public.

While with chemical pollution of a lake like Lake Michigan requires that we take a conservative approach because of the very long periods of time needed to flush out the lake, heat additions do not require the same conservative approach because the heat is rapidly lost to the atmosphere. Any deleterious effects that are found as the result of thermal additions are rapidly reversible once the heat input is stopped.

I foresee no harm from allowing the Zion Plant to operate provided that it is adequately studied to determine its effect on water quality. It will be from the operating records and studies of plants like Zion that we will obtain the information needed in order to revise our thermal standards a few years from now.

I wish to comment briefly on the FWQA cooling tower report that was presented here yesterday morning. It is difficult for me to understand how any agency would develop a report on the feasibility of using cooling towers on Lake Michigan without considering the chemical characteristics of the water.

The chemical characteristics of the water used in a cooling tower determine the amount of scale and corrosion in the heat exchange system. I doubt that any wet type cooling towers could be utilized on Lake Michigan without blowdown because of the chemical characteristics of the water.

Wet type cooling towers do cause water quality problems. The blowdown water is a concentrated brine, contains large amounts of algal nutrients and contains corrosion and scale control chemicals.

I am more concerned about the potential effects of cooling tower blowdown water on water quality than from the Zion type thermal discharge.

In Madison, Wisconsin, we have recently required that all cooling tower blowdown waters be kept out of the Madison lakes. I wish to point out that the operation of the wet type of cooling towers without blowdown requires that the salts that build up as a result of evaporation must be carried to the atmosphere. This results in continuous rain of salt particles and brine droplets in the area of the cooling tower. These salts can cause environmental contamination problems. They are deposited on the soil, houses, lawns, and the agricultural areas

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in the vicinity of the cooling tower. They are also washed to the lake with the stormwater.

I feel that insufficient attention has been given to the water quality aspects of wet cooling towers.

In summary, I do not foresee any significant adverse effects of thermal discharges such as the Zion Plant of Commonwealth Edison on the chemical parameters of water quality and the eutrophication of Lake Michigan. I feel that some of the statements made in the U. S. Department of Interior "white paper" on the thermal effects on water quality are not in accord with the best technical information available today. I advocate more liberal policy on thermal discharge standards than proposed by the U. S. Department of Interior provided that these standards are periodically reviewed and updated in accord with the information available at that time, and that each proposed thermal discharge is reviewed in order to protect any unique features or characteristics of the earth.

Thank you.

MR. STEIN: Thank you.

Before I throw this open to questioning, you confused me at one point. You referred to a former Interior Department official. What former Interior Department official?

DR. LEE: Mr. Klein. Is he still with you?

MR. STEIN: He sure is.

DR. LEE: All right. I am sorry.

MR. STEIN: That is corrected now. All right. Are there any other comments or questions?

MR. MACKIE: Yes, Mr. Stein.

I am not sure that Professor Lee is the gentleman to answer this question, but his discussion prompted the question, so I will ask it now, and that is: Will the projected power facilities in the year 1980 or 2000 result in overlapping of plumes in any of the areas of Lake Michigan?

DR. LEE: I do not feel qualified to answer that question.

MR. MACKIE: It was your discussion that prompted it, and I do think it would be of interest to the conferees to have some sort of an answer to that.

DR. LEE: Yes, that is extremely important in terms of determining the speed with which we must act on any standards, very definitely.

MR. STEIN: Are there any other questions or comments?

Mr. Currie.

MR. CURRIE: Yes. You mentioned, Dr. Lee, several times studies that have been made to prove the points which you made. I think we would be helped if we had copies of those studies.

DR. LEE: Yes, sir.

MR. STEIN: If we can, when?

DR. LEE: Well, some of these are in progress; some of them are in unpublished form at the University of Wisconsin. I would say it would take probably a month to get this into form.

MR. STEIN: Dr. Lee, you know we are going to have to come to a conclusion of the conferees. How much can you make available by next week?

DR. LEE: It would be very difficult to make any significant amount of information available by then. I have other commitments.*

MR. STEIN: Right. I understand that.

Are there any other comments or questions?

According to your statement, you say that as far as discharge from the Zion Plant is concerned, there are no adverse effects on the lake that you can determine.

DR. LEE: From the review of th situation, I predict no deleterious effects of this discharge.

MR. STEIN: Right. Well, glad to hear from you again. I guess the last time we heard from you, you said

* Information not supplied.

that the 67,000 tons of taconite tailings coming out of Reserve Mining would have no adverse effects on Lake Superior.

DR. LEE: The situation is still the same today as then.

MR. STEIN: I know, but the point is -- the idea is: Here you said it wasn't heat. It was nutrients there, when Dr. Mount and the other people said that taconites contained nutrients, there was still no effect from the nutrients.

DR. LEE: The evidence presented there did not support the position of Dr. Mount, in my opinion.

MR. STEIN: I understand that. I can't say you are inconsistent.

Are there any comments or questions?

If not, thank you very much.

MR. BANE: Dr. Robertson.

STATEMENT OF ANDREW ROBERTSON, ASSOCIATE
PROFESSOR OF ZOOLOGY, UNIVERSITY OF
OKLAHOMA, NORMAN, OKLAHOMA

DR. ROBERTSON: Mr. Chairman, honorable conferees, ladies and gentlemen.

I am Andrew Robertson, Associate Professor of Zoology at the University of Oklahoma. I have held my present position for the past 2 years, and previous to that I was Associate Research Limnologist with the Great Lakes Research Division of the University of Michigan for approximately 5 years. My work at Michigan entailed full-time research on Lake Michigan and led to approximately twenty publications concerning the biology of the lake.

I hold a B.S. degree in chemistry from the University of Toledo and M.A. and Ph.D. degrees from the University of Michigan in zoology. I have also spent 2 years in Edinburgh, Scotland, on an Office of Naval Research Fellowship with the Scottish Marine Biological Association doing research in biological oceanography. Attached hereto as an appendix is a complete list of my professional experience and honors, of my publications and of my memberships in professional societies.

(The Appendix above referred to follows.)

APPENDIX

PROFESSIONAL INFORMATION ON ANDREW ROBERTSON

EDUCATION

B.S.	1958, University of Toledo, Chemistry Major
----	1959, Scripps Institution of Oceanography, Marine Biology Major
M.A.	1961, University of Michigan, Bacteriology then Zoology Major
Ph.D.	1964, University of Michigan, Zoology Major

PROFESSIONAL EXPERIENCE

1957-58, Laboratory Assistant, University of Toledo

1958-59, Research Assistant, Scripps Institution of Oceanography

1959-60, Teaching Assistant, University of Michigan

1960-62, Teaching Fellow, University of Michigan

1962-64, Research Fellow, Scottish Marine Biological Association (Edinburgh)

1964-67, Assistant Research Limnologist, Great Lakes Research Division, University of Michigan

1967-68, Associate Research Limnologist, Great Lakes Research Division, University of Michigan

1968-69, (summers), Visiting Associate Professor, University of Michigan Biological Station

1968- , Associate Professor, Department of Zoology, University of Oklahoma

HONORS

Beta Beta Beta, 1957 (Biological Honor Society)

Phi Kappa Phi, 1958

Graduated B.S., magna cum laude, 1958

NSF Summer Fellow, University of Michigan Biological Station, Summers 1957 and 1960

Phi Sigma, 1960 (Biological Honor Society; Faculty advisor, 1965-1968)

University of Michigan Research Club, 1960

Sigma Xi, 1967 (Chapter council member, 1969-)

SOCIETY MEMBERSHIPS

American Society of Limnology and Oceanography

Ecological Society of America

International Association of Limnology

Midwest Benthological Society

American Association for the Advancement of Science

Southwestern Association of Naturalists

Oklahoma Academy of Science

PUBLICATIONS

1. Distribution of the Cladocera in the North Atlantic. 1964. Rep. Challenger Soc. 3, No. XVI
2. A method for studying herbivore standing crip with the Continuous Plankton Recorder. 1964. Ph.D. Thesis, University of Michigan. 97 p.
3. Particulate organic matter in Lake Michigan. 1965. Proc. Eighth Conf. Great Lakes Res., 175-181 (with C. F. Powers)

4. Some quantitative aspects of the macrobenthos of Lake Michigan. 1965. Proc. Eighth Conf. Great Lakes Res., 153-159 (with C. F. Powers)
5. The aging Great Lakes. 1966. Scientific American 215(5): 94-100, 102, 104 (with C. F. Powers)
6. A comparative study of Lake Michigan macrobenthos. 1966. Limnol. Oceanog. 11: 576-583 (with W. P. Alley)
7. The distribution of calanoid copepods in the Great Lakes. 1966. Proc. Ninth Conf. Great Lakes Res. 129-139.
8. Research ships of opportunity program Project Neptune Limnos. 1966. Univ. Michigan, Great Lakes Res. Div., Pub. No. 28, 25 p.
9. Comparison of the distribution of organic matter in the five Great Lakes. 1967. Univ. Michigan, Great Lakes Res. Div. Spec. Rept. No. 30, p. 1-18 (with C. F. Powers)
10. Zonation of the benthis environment in Lake Michigan. 1967. Univ. Michigan, Great Lakes Res. Div. Spec. Rept. No. 30, p. 78-94 (with C. F. Powers)
11. Design and evaluation of an all-purpose benthos sampler, 1967. Univ. Michigan, Great Lakes Res. Div. Spec. Rept. No. 30, p. 126-131 (with C. F. Powers)
12. A note on the Sphaeriidae of Lake Michigan. 1967. Univ. Michigan, Great Lakes Res. Div. Spec. Rept. No. 30, p. 132-135.
13. Lake Michigan biological data, 1964-1966. 1967. Univ. Michigan, Great Lakes Res. Div. Spec. Rept. No. 30, p. 179-227.
14. Direct observation from a submarine on the vertical distribution of Mysis relicta in Lake Michigan. 1967. Univ. Michigan, Great Lakes Res. Div. Rept. No. 30, p. 138-141 (with C. F. Powers and R. F. Anderson)
15. The distribution of organic nitrogen in Lake Michigan. 1968. Mich. Acad. Sci., Arts, Letts., 53: 135-151 (with C. F. Powers)

16. Subdivisions of the benthis environment of the upper Great Lakes, with emphasis on Lake Michigan. 1968. J. Fish. Res. Bd. Canada, 25:1181-1197 (with C. F. Powers)

17. Abundance, distribution, and biology of plankton in Lake Michigan with the addition of a Research Ships Opportunity Project. 1968. Univ. Michigan, Great Lakes Res. Div. Spec. Rept. No. 35, 43 p.

18. The Continuous Plankton Recorder: A method for studying the biomass of calanoid copepods. 1968. Bull. Mar. Ecol., 6(7): 185-223.

19. Direct observations on Mysis relicta from a submarine. 1968. Limnol. Oceanog., 13: 700-702 (with C. F. Powers and R. F. Anderson)

20. Identification of the copepodids of the Great Lakes species of Diaptomus (Calanoida, Copepoda). 1968. Proc. Eleventh Conf. Great Lakes Res., 39-60 (with S. C. Czaika)

21. Biological exploration in Lake Michigan from a research submarine. 1968. Proc. Eleventh Conf. Great Lakes Res., 117-123 (with C. F. Powers)

22. What is happening to our Great Lakes? 1969. Limnos, 2(1): 12-17

23. Unsung heroes. 1970. Limnos, 3(1), 18-22. (with S. C. Czaika)

24. The distribution of Calazoid Copepods (Calanoida, Copepoda) in Oklahoma. 1970. Proc. Okla.Acad. Sci. (Accepted for publication)

A. Robertson

I have been invited to present this statement by Commonwealth Edison Company and welcome the opportunity to express my views concerning the protection of this most valuable and unique resource. This statement represents my own viewpoint and does not necessarily correspond with the views of Commonwealth Edison Company.

I will restrict myself in this statement to the effects of the input of heat on the ecology and general biology of the organisms, exclusive of the fish, in Lake Michigan.

The setting of thermal standards for Lake Michigan is in some ways substantially easier than setting standards for concentrations of materials such as mercury, DDT, or lead. In the first place, the organisms in the lake, especially those which inhabit the upper waters, live in an environment which already undergoes extensive temperature variations. In adding heat we are, therefore, affecting the property of the lake for which the organisms inately have a substantial tolerance. Many of the Lake Michigan species are known to thrive in other lakes with temperatures, at comparable times and locations, above those contemplated in these harings. As a result, and in contrast to what may result from the addition of toxic chemicals, we are concerned here more with subtle alterations in the ecology, rather than with the direct threat of elimination of the organisms in the lake. Moreover, we do not have the problems of concentration in the higher levels of the food chains of the lake, with a resulting risk to human life. Even more importantly, heat added to the lake stays in the water for only a relatively short period of time and is then given off to the air. We are thus in a substantially better position than is true of the addition of toxic chemicals, since they accumulate both in the water and in the bottom sediments and our ability to clean them out of the lake is both much less certain and would take a far longer time. For the range of heat inputs under discussion here we need only stop the addition of heat to the lake and natural processes will reverse any detrimental effects that may have occurred.

Even with these inherent advantages in considering standards, I will attempt in this statement to take a quite conservative position. I do so because the question of what effect a thermal plume will have on the ecology of the included organisms is a complex and difficult one.

The effect of increased temperature on an organism depends on other physical-chemical factors in the environment, such as the concentration of oxygen and the intensity of light. It also depends on biological considerations such as the types and amounts of food present. Increased temperature may, for example, affect an organism by increasing or decreasing the abundance of its food. Other biological relationships of the organism, such as those with the species that prey upon it or compete with it for food or for sites for breeding and the like, further complicate the question. The history of the organism is also relevant since those raised in warm temperatures can often withstand higher temperatures than can members of the same species which were raised under cooler conditions.

The analysis, much less the understanding, of these relationships calls for a great deal of research and that research has not yet been done. For these reasons I have not attempted to predict in a detailed way exactly what will happen within the thermal plume. The studies Dr. Pipes has described to you should enable us, some months from now, to speak more accurately of the impact on individual species. Even more field studies will be required to evaluate the consequences to the ecology of the operation of a generating station such as that being built at Zion.

Nonetheless, it is quite possible, even without these studies, to form an opinion concerning the danger to the ecology of the lake from the addition of heat by generating stations such as Zion. I have assumed, for the purposes of this statement, that if there is a reasonable likelihood of a substantial change in the ecology of the lake due to a postulated heat addition, the addition of that heat is undesirable. Having taken that conservative position, let me immediately say that I do not favor a policy of prohibiting all discharges of heated water to the lake, or of limiting such discharges to 1 degree F. above the natural water temperature at the point of discharge.

I regard any such policy as prohibitive and less than fully rational, rather than merely conservative. As an ecologist I feel that we must adapt our culture so that it fits into and harmonizes with the ecology of our natural environment. Quality of life depends on preserving our natural resources while at the same time using them for our benefit. My analysis of the ecological effects of the heat additions contemplated in this hearing convinces me that they pose very little danger to the ecology of the lake. Let me now turn to the basis for my opinion.

In order to determine the consequences of adding heat to the lake one must know the magnitude and distribution of those additions. I accept Dr. Pritchard's demonstration that the existing and presently proposed powerplants would have only a negligible effect on the average temperature of the water in the entire lake. The problem lies in evaluating the possible consequences of more substantial but localized increases in water temperature.

I have used the predictions contained in Case IV of Dr. Pritchard's statement concerning the distribution of excess temperatures which will result from the discharge of condenser cooling water. With his predictions of the size of the thermal plume in mind, I will attempt to look at the major functional groups of organisms in the lake and ascertain the likely consequences to them of the proposed thermal additions.

Effects on the Bottom-dwelling plants

Where the water is shallow enough to allow penetration to bottom of sufficient light fo. growth aquatic plants are often found on the bottom of Lake Michigan. In most places, except in protected areas such as bays, these plants are restricted quite largely to microscopic algae. These plants often play an important part in the ecology of nearshore areas. A notable exception to small size is the alga Cladophora which forms the major part of the green mats often found covering rocks and other nearshore surfaces.

It is well established that one of the major factors controlling the types of these algae is the water temperature. Substantial permanent increases of temperature in an area would undoubtedly change the types and possibly the amounts of bottom-growing algae. Thus, it would seem undesirable to have any but a very small area of the bottom of the lake exposed to substantial temperature increases from thermal additions.

A special problem with temperature increases are their effect on Cladophora. Under certain conditions, especially where plant nutrient concentrations are high, the mats of this alga can be so thick as to be detrimental to recreational uses of shores, both as slimy materials covering the bottom and, after parts of the mats have become dislodged, as material floating on the water and piling up and decaying on the beaches. The effect of increased temperature on this alga in Lake Michigan is uncertain at present. Studies elsewhere have indicated increased temperature may either increase or decrease the growths of this material, depending on the species present, the temperature changes involved and probably other factors.

Thus, until we have further predictive capacity it would seem prudent to avoid running the risk of increasing growths of Caldophora over an appreciable area.

However, discharges such as those described in Dr. Pritchard's Case IV involve very little danger of alterations to any of these bottom plants. The outfalls would be directed away from shore and in deep enough water so that little if any of the bottom would experience substantial temperature changes.

Effects on the Bottom-dwelling Animals

A variety of animals live on the bottom of the lake. Important forms include the amphipod Pontoporeia affinis, the mysid Mysis relicta, several species of oligochaetes, a number of spaeriid clams, and several types of insects especially chironomid larvae. Smaller animals such as nematodes, ostracods, bryozoans and rotifers are also well represented. The animals occur not only in shallow water, as with the plants, but are found all over the lake bottom, even in the deepest water. There is little doubt that these organisms are sensitive, to a greater or lesser extent, to temperature changes. The animals that live in the deep waters, such as Pontoporeia and Mysis are thought to be especially sensitive because they live in an environment that is very cold all year around and so have not evolved much tolerance to temperature variations. This raises the possibility that major changes in the temperature of the deep waters could have adverse effects on these animals. Fortunately, however, warm water is less dense than cold, and so heated discharges should stay well above the deep waters except in the unlikely case where they are released there. All the Lake Michigan stations of which I am aware contemplate outfalls very near the surface and well away from these deep waters and so represent no perceivable danger to the animals occurring there.

The outfalls are, however, located where they might influence the nearshore bottom animals. This situation is comparable to that for the bottom-dwelling plants; the effect will depend on the distribution of the excess temperature. However, if Dr. Pritchard's Case IV is assumed then only minimal temperature changes along the bottom will result, and there should be little likelihood of noticeable effect on the bottom animals.

It seems then that proper design of generating stations can remove dangers to the bottom animals. However, standards eliminating the possibility of temperature changes to the deep (hypolimnion and thermocline) waters and restricting the shallow areas that could be exposed to temperature changes should be set.

Effects on the Plants in the Plankton

Many species of algae, including especially diatoms and green algae, are found suspended in the waters of Lake Michigan. These members of the plankton are vitally important as they are the primary agents of photosynthesis in the lake, and so the primary means by which organic matter is produced. The algae are eaten by small animals which are eaten, in their turn, by larger animals and so on. Thus, directly or indirectly most of the organisms in the lake depend on these planktonic algae as their source of energy and materials needed for life. Because of their extremely important role in the ecology, it is especially important to avoid changes to these algae.

There is evidence that substantial permanent changes in temperature of a lake can change the types and amounts to these algae. However, this evidence mainly applies to cases where an entire small lake has experienced the temperature increase, and so the algae are continuously exposed to the increased temperature. The contemplated thermal additions to Lake Michigan are quite different; they will only affect limited local areas and the algae will only be exposed for a limited time.

A. Robertson

The situation in terms of the effect of large power stations on planktonic algae can be separated into two distinct problems:

1) What will be the effect on the algal cells that are present in the water passing through the station as part of the condenser cooling water?

2) What will be the effect on the larger numbers of cells that are present in the water that dilutes the warmed cooling water after discharge?

Let us first consider the situation for the algae included in the cooling water, using the situation at Zion as an example. Both units at Zion Station together are expected to have a total flow of 1,530,000 gallons per minute with a rise in temperature for this water of 20 degrees F. The effect of this increase of temperature on the algae in the water will certainly vary with the species present.

However, if for the sake of argument we were to assume the unlikely situation that all were killed, it seems extremely unlikely that any noticeable effect on the ecology of the lake will result. My calculations indicate that less than 1 out of each one-half million parts of water in the lake will flow through the station per day. The planktonic algae tend, to a limited extent, to be concentrated in the upper layers of the lake, the part from which the condenser cooling water will be drawn. Thus, a somewhat greater proportion of the algae will flow through the condenser than the proportion of the lake's volume that flows through the station would indicate.

Still, it seems assured that only a very small fraction (much less than 1 in 100,000) of the algae will be exposed to the 20 degrees F. temperature increase per day. Further, planktonic algae are known to reproduce quite rapidly, often once every few hours or days. This process is part of a natural cycle in the lake of growth and reproduction of some cells coupled with death and decay of others. The nutrient materials freed by the decay of the dead cells provide the building materials for the growth of others. Thus, it seems likely that any cells killed by exposure to the cooling water will be replaced quite rapidly as their materials are made available to other cells as part of this natural cycle. Therefore, with only a very small fraction of the cells in the lake being exposed to the temperature rise associated with inclusion in the cooling water, and with any cells in this fraction that are killed being replaced quite quickly, it seems extremely unlikely that the effect on the algae in the cooling water will give any noticeable effect on the ecology of the lake.

What then of the greater amounts of algae that are exposed to increased temperatures by being in the water that mixes with the heated outflow after discharge? Still, the proportions of the algae of the lake affected per day are very small.

For the situation at Zion, it is calculated that, to reduce the temperature of the cooling water to a temperature 2.5 degrees above ambient, will call for a dilution of each part originally at 20 degrees above ambient with 8 parts of ambient temperature water. This means that no more than about 1/70,000 of the water in the lake will be heated to 2.5 degrees above ambient or more each day.

If we consider the more generalized generating station of Dr. Pritchard's Case IV, we again find that very little of the lake will be affected. He calculates the surface area of the lake contained within a number of different isotherms of excess temperature. Even for an excess temperature as small as 2 degrees F., the area exposed is only 99 acres. This is out of a total surface area for the lake of approximately 14.3 million acres.

Further, the exposure of the organisms to these excess temperatures is only for a very limited time. Dr. Pritchard's calculations show the maximum time of exposure at excess temperatures of 2 degrees or more to be only 1.5 hours, with the time much shorter yet at higher temperatures. Thus, even for the dilution water only a very small fraction of the algae in the lake will be exposed per day. Further, for most of the cells the exposure will be to much less than a 20-degree increase in temperature and for only a few hours. It is very doubtful that an increase of temperature of a few degrees for a relatively short period of time will have much permanent effect on the algae cells. Even if it does, however, they should be replaced quite quickly by further reproduction of the remaining cells.

One other possibility, that the increased temperatures will cause changes in the species present, has been suggested. If it were possible for certain parts of the water volume to be permanently warmed above ambient, this could happen. However, as the heated water will be quite quickly cooled by dilution, the exposure to increased temperatures for any particular parcel of water will be quite restricted in time. Thus, there will be little time for new species, favored by the increased temperatures, to be established in a parcel of water before the water is returned to ambient temperature and the conditions favoring the naturally-occurring assemblage of algae.

There seems little likelihood then that temperature conditions from a station like the one proposed at Zion or suggested in Dr. Pritchard's Case IV will have any appreciable effect on the ecology of the planktonic plants in the lake. This conclusion receives support from the field study of Beer and Pipes (1968) at the existing Waukegan power station south of Zion. In their preliminary study of the effects of the thermal discharge from this station, they found no evidence of changes in the types or amounts of plant plankton.

Effects on the Planktonic Animals

Many small animals live with and feed on the planktonic plants. These include small crustaceans such as copepods and cladocerans, rotifers and protozoans. Much of what was said previously concerning the plants also applies here. As with the plants, only a minute fraction of the planktonic animals in the lake will be exposed per day to temperature increases at a station such as Zion or Dr. Pritchard's Case IV.

There is one difference in regard to the animals that should be briefly considered, the rates of reproduction for the planktonic animals tend to be every few weeks or months rather than every few days as with the plants. The slower rates of reproduction mean that any animals which may be killed by the elevated temperatures of the cooling water will not be replaced as fast as will the plants. However, their reproductive rates are still very rapid in relation to the proportion of the animals in the lake that will be exposed per week or per month to the thermal discharge.

Further, personal experience with these and similar animals leads me to believe that many of them will survive the short exposure to a 20-degree increase of temperature that will occur with the Zion station. Thus, the decreased reproductive rates seem to mean little in terms of increased damage to the ecology of the lake. Beer and Pipes (1968) have shown with the planktonic animals, as with the plants, no detectable effect of the thermal discharge of the Waukegan station. This work supports my own conclusion that, given the rather short residence times in the warmer water, no ecological damage will occur.

Conclusions

My analysis of the likely effects of a generating station such as Case IV leads me to conclude that the thermal discharge from such a station is likely to have little if any detectable effect on the ecology of the organisms, exclusive of the fish of Lake Michigan. I reach this conclusion despite our present inadequate knowledge of the details of the environmental physiology and ecology of the organisms in the lake. Although there is certainly a great deal yet to be learned as to the exact results of any particular thermal discharge, the extremely small fraction of the lake affected has convinced me that the detrimental effects, even if badly misjudged, would still be relatively minor.

Of course, stations of other designs and producing quite different temperature changes in the lake might have much more effect on the ecology. Consequently, consistent with the conservative position I have taken, I favor standards forbidding discharges that would of themselves or in combination with the existing discharges change the overall temperature of the lake to any appreciable extent. For localized situations the amount of bottom area or shoreline exposed to elevated temperatures should be restricted as should the time any mass of water may be exposed to appreciable temperature increase. Standards of this type will protect the ecology of the lake, while still allowing the development of a number of generating stations such as Zion.

Thank you.

MR. STEIN: Thank you very much.

Any comments or questions?

Mr. Dumelle.

MR. DUMELLE: Dr. Robertson, you speak quite often in your statement about the proportion of plankton and animals in the lake -- 1/100,000, 1/70,000. I take it from this you disagree with the Federal position that the inshore waters are a different body of water and comprise only 4 percent of the lake, and in effect is a second body. Do you disagree with this?

DR. ROBERTSON: From a physical standpoint I am not in a position to disagree. All I can say is that from my experience on the lake, having been out on the lake a number of months of my life, and having looked at the biology of the lake, I have not been able to find any appreciable differences in the types of organisms between the near shore and offshore zone in the plankton. This leads me to believe, then, that there is no particular barrier to movement of the planktonic organisms between these two areas.

Dr. Pritchard seems to have at least suggested -- and I am not fit to judge this -- but he has certainly presented some evidence suggesting that the reason for this is that the physical exchange between these two areas is quite large. I would state further, from my own experience, that I know of some organisms that are known in other lakes to be near shore organisms and yet in Lake Michigan we find them in the middle of the lake.

MR. DUMELLE: Well, I do want to point out to the conferees that if the inshore waters, in fact, act as a separate body of water and have only 4 percent of the volume of the lake, then you are multiplying the numbers which Dr. Robertson has mentioned by 25 so that instead of 1/100,000, as he mentioned, we are talking about 1/4,000, and instead of 1/70,000, we are talking about 1/3,000, and this to me begins to become significant and I think a great deal depends on the validity of that separation.

MR. STEIN: Well, just one moment.

Do you want to comment on that?

DR. ROBERTSON: I would just say that I agree that it is significant, and if I had only 4 percent of the lake to look at in this work, I would want to look at this again on my conclusions.

MR. STEIN: Mr. Dumelle.

MR. DUMELLE: Yes.

Dr. Robertson, are you familiar with the standards set by the State of Maryland for the Calvert Cliffs nuclear plant?

DR. ROBERTSON: No, sir, I am not.

MR. DUMELLE: In the permit for the plant, as I understand it, they restricted the detention time within the condenser to 4 minutes, and the temperature rise to 10 degrees Fahrenheit.

Could you state, in your opinion, from your experience on time-temperature mortality rates, whether the 20 degree 2-minute detention time in the Zion Plant is equivalent to the 10 degree 4-minute ratio of the Calvert Cliffs Plant? What I am asking is: Is the dosage rate or the mortality rate linear or is it some other relationship for any given type of organism?

DR. ROBERTSON: I am not a physiologist, but my opinion on this is that I have no reason to believe that it would be linear.

MR. DUMELLE: Would you think that the higher temperature would cause more mortalities than the lower temperature, even though the product of the two -- the time-temperature --

DR. ROBERTSON: Talking 20 in 2 minutes and 10 in 4 minutes, is that correct?

MR. DUMELLE: Yes, sir.

DR. ROBERTSON: My opinion again on this is that the differences would be -- the different effects between these two would probably be relatively minor.

MR. DUMELLE: Thank you.

MR. STEIN: Are there any other comments or questions?

You referred several times to Dr. Beer and Dr. Pipes. Are they still working together?

DR. ROBERTSON: Yes, sir, I believe they are.

MR. STEIN: The next time they prepare a draft, I wish they would let me know.

Thank you very much.

DR. ROBERTSON: Dr. Pipes will be testifying later and I am sure he will give you copies of his work.

MR. BANE: Dr. Raney, please.

STATEMENT OF EDWARD C. RANEY,
PROFESSOR OF ZOOLOGY, CORNELL
UNIVERSITY, ITHACA, NEW YORK

DR. RANEY: My name is Edward C. Raney. I am Professor of Zoology at Cornell University, Ithaca, New York, and Director of Ichthyological Associates, 301 Forest Drive, Ithaca, New York. I hold the M.S. (1935) and Ph.D. (1938) in Zoology from Cornell University and my scientific specialty is the study of the ecology, behavior and systematics of fishes. I have been involved in teaching and research in biology at Cornell since 1936, and I have been a full professor there since 1952. For the past 30 years many of my field and laboratory studies have involved the effects of heated effluents on fishes and other aquatic organisms. These studies have resulted in more than 100 published papers in the primary literature. During the course of these studies I prepared and published in 1969 a bibliography of more than 1,800 published papers under the tital of "Heated Effluents and Effects on Aquatic Life with Emphasis on Fishes."

Ichthyological Associates, which is an unincorporated group of aquatic biologists involved in ecological research, was founded by me in 1966 to make ecological investigations in situations which have been or were about to receive heated discharges.

This statement is presented on invitation by the Commonwealth Edison Company, Chicago, Illinois. The observations, opinions and conclusions presented herein are mine and do not necessarily represent the views of the Commonwealth Edison Company or Cornell University.

This presentation deals with fishes, and particularly those which live in or might ultimately be found in Lake Michigan. Although I have not made personal studies of Lake Michigan, I am familiar with the species which now inhabit the lake, have studied many of them, and have perused the considerable literature which is now available on the fauna of Lake Michigan and have conferred with many of the active research workers now studying the lake.

I am familiar with the general principles regarding temperature and fishes which have been based on many studies made over the past 40 years. I have also had the opportunity to study the results of the introduction by jet of heated discharges as measured by hydraulic and other models and am familiar with the scholarly but practical statement which was presented before this group by

Dr. Donald W. Pritchard. Also, I have examined many heated outfalls in eastern United States and have advised or participated in detailed studies of many.

Thus, I appear before you as a student of fishes and other aquatic organisms who has the greatest regard for living things, including people. My studies convince me that with proper siting, based on ecological and hydrological studies, and the careful design of intake and discharge structures, that Lake Michigan can be used as a source of disposal of waste heat which would result from the production of a large amount of electricity. I am also convinced that the present and future demands for electricity coupled with the present and prospective economic situation and with due regard for human ecology, including the "good life," that one of the highest and best uses of some water from Lake Michigan would be as cooling water for large nuclear powerplants. This, I believe, can be done without detrimental effects to aesthetic or recreational values including the natural (or unnatural) biota. In my opinion, once-through cooling is to be preferred to the use of the enormous and ugly cooling towers which are beginning to dot the landscape of inland areas. Little or no survival is likely of the organisms in water which is needed to supply the evaporative cooling in these towers

I emphasize that my remarks are not necessarily applicable to other lakes, rivers and streams. However, other large, deep, cold lakes should be particularly examined as possible sources of cooling water and no doubt they will be used in the future as additional studies show the ecological realities and after the present near-hysteria regarding thermal discharges has subsided.

Fishes of Lake Michigan

The deeper or offshore waters of Lake Michigan originally had a fish population dominated by lake trout, lake whitefish, and a number of related species known as lake herring, bloater or chub, and the burbot. Some trout were present including the introduced brown and rainbow, but these normally utilized the streams for spawning and it was here that most were available to the sport fishery.

In inshore waters, the yellow perch, walleye, a number of species of small suckers, minnows and darters were found, particularly in the summer. All of these fishes are subject to year class fluctuations wherein an occasional spawn would be much more successful and could dominate the fishery for a species for several years.

With the introduction of the landlocked form of the predatory sea lamprey (about 1936) from a point below Niagara Falls where it had occurred for a long period, the populations of larger fishes such as lake trout and lake whitefish were reduced to a point where commercial lake trout fishing was virtually abandoned. The alewife and smelt were also introduced. The former is useful as a forage fish and at times occurs in great numbers and is subject to large dieoffs which can create a tremendous public nuisance.

More recently the coho salmon was introduced and is maintained by stocking. It is now a local and important source of sport fishery. Even more recently the chinook and sockeye salmons have been introduced.

Large expenditures have been made to reduce the lamprey population and lake trout have been stocked and the population has increased. Some taken recently have shown signs of scarring by the lamprey which, although reduced by various control methods, is still present.

Thus, it may be seen that the major changes in fish populations which have occurred in recent years is not associated particularly with the industrial activities of man, but are due mainly to interactions of fish species. Many are optimistic about the present fishery based upon the several species of Pacific salmon, but particularly coho. However, knowledgeable biologists expect problems.

E. C. Raney

Temperature

By a long evolutionary process aquatic organisms have adapted to various environmental factors. Water temperature is one of the most important and may become a problem to a given species of fish when by natural or other means the water temperature increases to a point where it reaches or exceeds the lethal temperatures for a critical period of time, and when escape is impeded. However, motile species such as fishes may (and do) avoid such areas where temperatures are critical.

Water temperatures below lethal levels may also be a problem if blocks to the migration or other seasonal movements are such as to prevent spawning. Normally this generalization applies to anadromous (uprunning) fishes such as the smelt, trout or salmon. However, these migrations are usually timed in the spring or fall so that the most critical season of high summer temperatures is avoided.

Temperature Requirements of Fishes

1) Fishes are "cold-blooded." The body tissues quickly change to the temperature of the surrounding water because the gills must be exposed to permit the passage of oxygen and carbon dioxide.

2) Fishes can perceive minute differences in temperature; much less than 1 degree F.

3) Fishes have a lower and an upper lethal temperature limit or tolerance. The lethal temperature is specific for each species and the requirement for different stages in its life history such as spawning, development of eggs, development of fry, growth and development of young, etc., may differ. These limits permit adjustment to differences in seasonal temperatures as well as of those of 5 degrees F. or more locally from place to place, from day to day, or night and day. The juvenile and adult of each species of fish may have a different upper lethal temperature limit. The actual lethal point may be modified by other factors, such as dissolved oxygen, carbon dioxide, salinity, silt, light intensity, and ions of heavy metals.

4) Fishes and other aquatic organisms are able to acclimate to a given temperature (within the lethal limits) and do so regularly with temperature changes accompanying the seasons. A fish when permitted to acclimate may choose a final preferred temperature.

5) Once acclimated to a given temperature, fishes and other aquatic organisms acclimate more readily to an increase than a decrease in temperature.

6) The activity of fishes and other aquatic species usually increases with a rise in temperature. However, the relationship can be reversed.

7) It has been shown that fishes can and will follow a temperature gradient. They normally follow this gradient to or toward their preferred temperature.

The behavior of a given fish species often depends on the magnitude of change of temperature to which it may be exposed. It may be attracted to the higher (or lower) temperature, it may avoid by swimming away from higher (or lower) temperatures, or it may not react.

Observations on the behavior of fishes as affected by temperature have been studied. These experiments are usually done with young or yearling. One other point that I would like to make, because some of the results obtained on laboratory studies are applied to a few conditions when perhaps they should not -- or perhaps they do not apply. Such studies are, and in some respects probably always will be, relatively limited because it is necessary to work with small fishes or the smaller sizes of large fish species due to the nature and size of available equipment and funds. Space and time limitations are obvious. Normal behavior patterns involving territory, pecking order, and the like, may be disturbed.

In order to acclimate fishes to certain temperatures they are usually fed regularly and this may result in a conditioned response. Reactions to artificial periods of light and dark as opposed to normal photo-period may give difficulty. Some bottom fishes must or prefer to have contact with the bottom or other objects. Other fishes prefer shelters like brush piles, and still other cannot tolerate crowding. Typical schooling species may not act normally when a single specimen is studied. Concurrent effects of light intensity, oxygen, and pH may be important.

Preferred Temperature

A species of fish, which is used to or acclimated to a given water temperature may move toward (or away from) a higher or lower temperature. This is illustrated by the results of the following experiment on the alewife, which is now abundant and ecologically important in Lake Michigan. In August six specimens of alewife were acclimated at 77 degrees F. for 48 hours. They were introduced into an experimental apparatus where the water temperature was 74 degrees F., and they were offered two alternatives, 74 degrees F. or 82 degrees F. They proceeded to the area and occupied water of 82 degrees F.

This, of course, illustrates the point that if they like it, they can go for a warmer temperature.

After a short period, these same six specimens, and we used six because it was a schooling species, were introduced into a similar experimental tank where the water temperature was 80 degrees F., but where the alternative temperature of 86 degrees F. was available. The latter temperature was avoided. And this illustrates the simple proposition that if the temperature is high they avoid it and swim away from it, and this is what they do with heated plumes.

In another experiment, using six specimens, the results were similar. They were acclimated at 77 degrees F., introduced into water of 75 degrees F., and were attracted to water 83 degrees F. A short time later the same fishes were placed in water of 80 degrees F. They avoided the alternative temperature which was 86 degrees F. In the above experiments the water temperatures exceeded those generally expected in Lake Michigan. However, it illustrates the expected reaction of a species, such as the alewife, if and when it comes close to a heated plume. Anxiety with regard to an expected large mortality of the alewife, if and when it comes close to a heated plume. Anxiety with regard to an expected large mortality of the alewife in heated plumes is unfounded and except under unusual conditions no such mortality is expected.

Additional data are given in Table 1 with regard to some fishes found in Lake Michigan.

(The table above referred to follows.)

Table 1 -- The Final Preferred Temperature in degrees F for Various Species of Fishes Found in Lake Michigan. Young or Yearling Fishes were Used in the Experiments Except Where Noted by Asterisk Where Two-Year-Old Fish were Involved. Modified after Ferguson, 1958.

Species	Final Preferendum	Authority
Carp	89	Pitt, Garside and Hepburn (1956)
Smallmouth Bass	82	Fry (Ms., 1950)
Yellow Perch	75	Ferguson (1958)
Muskellunge	75	Jackson and Price (Ms., 1949)
Burbot	70	Crossman, et al. (Ms., 1953)
Yellow Perch	70	McCracken and Sparkman (Ms., 1948)
Brown Trout*	54-63	Tait (Ms., 1958)
Brook Trout	57-61	Graham (1948), Fisher and Elson (1950)
Sockeye Salmon	58	Brett (1951)
Rainbow Trout	56	Garside and Tait (Ms., 1958)
Whitefish*	55	Tompkins and Fraser (Ms.,1950)
Lake Trout	54	McCauley and Tait (Ms., 1956)
Chinook Salmon	53	Brett (1951)

Only a few with relatively high temperature preferences are listed. The carp, for example, has a temperature preference of approximately 89 degrees F. The smallmouth bass, yellow perch, muskellunge and burbot are usually spoken of as cool water fishes which in experimental apparatus have shown preference of from 70 degrees to 75 degrees F. In most the salmonid fishes and their relatives, which are of major interest in Lake Michigan, both sport and commercial, the preference is generally from 53 degrees to 63 degrees F. Obviously these cold water fishes are not going to be found at these temperatures at all times but they do tend to move toward these temperatures if available and other needs, such as food, is met in such localities.

Lethal Temperature

The lethal temperature is that at which a fish dies after a given time. Such temperatures are avoided by motile aquatic organisms. Fishes avoid the hotter parts of plumes.

Fishes are occasionally killed near heated water outfalls where temperatures increase or decrease rapidly. This seldom happens. These are usually high temperature phenomena. When it does, small free-living fish or young are mainly affected. Most large fish are able to swim away to safety. Sudden increases in river temperatures of 11 degrees to 16 degrees F. are sufficient to drive fishes away from lethal conditions.

This may be illustrated by findings in the mile-long canal carrying heated water from the Connecticut Yankee Power Company plant at East Haddam, Connecticut. Incidentally, the plant has been in operation for some 3 years now. I have been involved in these studies since 1965 as a member of the advisory board. Connecticut Yankee is potentially a much more adverse situation than is Zion. Cooling water is carried to the river through the canal. In 1968, biolgosits observed movements of fishes in and out of this canal. Water temperature differences may be as great as 19 degrees F. Fishes were concentrated in the canal up to a water temperature of 95 degrees F. No fishes were found in the canal in the range between 95 degrees and 102 degrees F.; the latter was the highest temperature recorded in the summer of 1968. Fish were collected again when the temperatures in the canal dropped to 93 degrees F. The great concentration in the outfall canal is illustrated by the results of a collection on 7 November 1968, when 1,466 fish were taken in a 5-minute trawl haul. Yet, no mortality was observed, and there were people observing them. In a canal we estimated that 40,000 catfish were present at the time under these conditions.

At a later time after 4,000 of them were tagged, and they left the canal, some of these fishes were found as far as 50 miles away. Here again, there was no evidence of mortality, no direct observation of them. This is a very important point.

Pronounced changes in effluent temperature at Lake Michigan plants will rarely occur and mortalities of fishes and other biota caused by temperature differences are predicted to be nil. During the critical period in summer in the mixing zone few or no fishes are expected to be present and other motile aquatic organisms may be scarce.

However, a concentration of fishes and an extended period of feeding may often occur in the heated water during the cold season. An attraction to the warmer water in spring and fall often creates a valuable unseasonal recreational fishery.

Winter Temperatures

All of the species found in and near Lake Michigan are able to live in winter temperatures of 32 degrees to 40 degrees F. Many of the important sport and commercial fishes in Lake Michigan prefer cold or cool water. Some species which are normally found in the shallows in summer become inactive when the water temperature is below 40 degrees F. and some go into or near the bottom silt; they are not usually active until early April or May when the water again reaches approximately 40 degrees F.

Avoidance

It is obvious that lethal maximum temperatures for motile organisms are inappropriate to predict the effects when such species encounter higher temperatures (plumes) because such a measure ignores the behavior of the organisms and the time which an organism might be in contact with such a temperature. It is proper to use such a measure only for organisms which cannot avoid and which remain in the increased temperatues. For example, some benthic organisms. Further, it is important that such conditions such as oxygen, salinity, pH, and time of exposure be considered. A far more appropriate measure is the upper avoidance temperature.

It is obvious that all parts of any lake, such as Lake Michigan, cannot be all things to all fishes at all times. The distribution of various species varies with season. Because of its depth and stratification the depper water offers a habitat to those fishes which must have cool water. Shallow areas, in the case of the lake trout, or tributaries, in case of smelt, provide necessary spawning grounds. Plants would not be constructed in areas where migratory paths would be affected. The warm water fishes, among those underlined in Table 2, are expected to be, and normally are, found in the shallower areas in summer.

(The table above referred to follows.)

Table 2 -- Provisional Maximum Temperatures Recommended as Compatible with the Well Being of Various Species of Fish and their Associated Biota. From: Table III-1, Water Quality Criteria, Report of the National Technical Advisory Committee to the Secretary of the Interior, April 1, 1968, Washington, D. C. Federal Water Pollution Control Administration.

93°F	Growth of catfish, gar, white or yellow bass, spotted bass, buffalo, carpsucker, threadfin shad, and gizzard shad.
90°F	Growth of largemouth bass, drum, bluegill, and crappie.
84°F	Growth of pike, perch, walleye, smallmouth bass, and sauger.
80°F	Spawning and egg development of catfish, buffalo, threadfin shad, and gizzard shad.
75°F	Spawning and egg development of largemouth bass, white, yellow and spotted bass.
68°F	Growth or migration routes of salmonids and for egg development of perch and smallmouth bass.
55°F	Spawning and egg development of salmon and trout (other than lake trout).
48°F	Spawning and egg development of lake trout, walleye, northern pike, sauger, and Atlantic salmon.

Note: The fishes underlined above are those found in Lake Michigan.

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These warm water species are those which are expected to be most common near the heated outfalls. However, except perhaps for occasional short periods the cold-water fishes never were abundant in these shallow areas. Parenthetically I remark that the beach bottom plant which is presently under construction and will go into operation next year, also has a jet effluent, and the artificial alum plant, also known as the Salem plant, located on the lower Delaware River, which is under construction, will go into operation in two years. It has the same type of a jet effluent which was worked out by Don Pritchard and his partner at the Vicksburg model.

Thus it is predicted that for smelt, brook, brown and rainbow trout, lake whitefish, chubs, and salmon, no mortalities would be involved nor would significant mortalities occur in the food chain which could possibly affect those fishes.

Summary

1) Dire prediction by some ecologists over the years have failed to materialize in the situations I have studied. I am confident that predictions of disaster for the ecosystem from heated effluents for Lake Michigan will be proven to be false. Some changes will occur. Some may be considered for the better. I suspect that many

predictions appear to be based on the uneasy feeling that heated water is a pollutant in the usual sense (domestic-chemical). Heated water does not leave a residue and ultimately passes to the atmosphere, and is not a pollutant in the usual sense.

2) My conclusions are based upon personal experiments with heated water and observations at heated outfalls of both nuclear and other steam plants located on the Connecticut, Hudson, Delaware, and Susquehanna Rivers, as well as a careful study of hundreds of published reports.

3) These conclusions are also based on the design of the Zion plant of Commonwealth Edison Company and upon the discharge arrangement (Case IV) as given by Dr. Donald W. Pritchard. It assumes a jet effluent with rapid turbulent mixing and a minimal disturbance of the environment by heated water. Each site and nuclear plant is unique in some respects and the following predictions made for the Zion site may not be applicable to others, in my summary.

4) Most organisms including fishes will be denied some living space. At Zion this involves a very small area close to the heated outfall.

Yesterday I believe that Mr. David Currie asked one of the witnesses with regard to this matter -- I predict that for any of these heated outfalls that for an area very close to the pipe that you are going to have some loss. If it hits the bottom you are going to lose some benthic organisms. However, in this connection at the Connecticut Yankee atomic plant we have found that just off the heated canal, which may be 19 degrees above ambient, that the benthos is actually increased. I think that it is -- as a conservative measure, that you can expect some denial of living space.

What does this amount to? In most cases, a few acres.

5) Even during the worst summer conditions, the isotherms produced by using a jet effluent indicate that outside a small mixing zone near the effluent most summer water temperatures would be below the upper lethal temperatures for the fishes and associated organisms normally found near the Zion plant in the summer.

Basically the problem of lethality with regard to fishes has been over-emphasized, and I agree with Dr. Pritchard in the study of reported cases -- and I have studied hundreds of them -- in most of these cases of reported mortality, it has been due to chlorine or other chemicals such as zinc and sometimes copper.

6) Hardly any of the shallow shore area located near the Zion plant will be blocked by temperature, and production will be affected only in the area close to the small plume. The fishes which are normal inhabitants of the shore habitat during the warmer summer months will be unaffected except for a few acres near the outfall.

7) Even under the most critical summer conditions it is not expected that the fishes or other biota will be placed under serious stress, which would affect the size or the quality of the population or have any effect on the ecosystem.

8) Except for a few acres near the base of the plume, the seasonal temperature requirements for reproduction and other aspects of the life history of the fishes which are seasonally present in the Zion area are predicted to be satisfactory.

9) Fishes which normally live in the Zion area are adapted to the changes in temperature which occurs in the environment at the several seasons and may avoid, be attracted to or not react to temperatures in various parts of the plume.

10) No permanent reduction in species diversity in fishes or associated biota is foreseen either in the vicinity of the plant or in the lake in general due to the

operation of the plant. Some local but insignificant changes may occur seasonally. Compared to natural changes including year class fluctuations, any change in fish populations which might be attributed to heated effluents would be miniscule and insignificant to a commercial or sport fishery.

11) The heated effluents from nuclear powerplants are not expected to affect the pier fishing for yellow perch in Lake Michigan. This fishery has fluctuated from year to year and is expected to continue to do so.

12) Many of the fishes present such as walleye and yellow perch are subject to great variation in year class strength. These usual year-to-year variations will not be affected significantly by the predicted patterns of heated effluent from the Zion plant.

13) The eggs and larvae of fishes are not expected to be a problem. Most of the eggs are deposited in nests or are heavier than water and stick to the bottom. Relatively few are present in the water column. At Zion the fast passage through the condenser system would involve few eggs and larvae and cause insignificant mortality. These are the results of the experiments done in California back in 1950.

14) Young chinook salmon have passed through

condensers with a 25-degree F. rise and fast passage (approximately 5 minutes) with little or no mortality; 95 percent or more survived for 10 days after the trials. Actually, the report after 10 days shows no mortality for chinook salmon and 95 percent of the striped bass passing through the same system survived for 10 days after the passage, not causing damage to the ecology of Lake Michigan.

15) If mortalities occur, they are likely only close to high temperature plumes. The design of the Zion plume avoids this problem.

Conclusion

The approval of the use of a reasonable mixing zone set on the basis of engineering, ecological, hydrological, and meteorological studies will permit the use of many points along the shore of a cold lake, such as Lake Michigan, as Dr. Pritchard has so ably pointed out.

We have the knowledge to design powerplants so as to mitigate possible environmental effects. Such large structures will cause some changes in the local environment. However, I believe they can be operated without hurting recreational uses including the sport and commercial fisheries.

Properly designed discharges will have no effect outside of their mixing zones, and even within those zones, very little area is exposed to a substantial temperature increase. A 1-degree F. to 5-degree F. rise or fall in temperature has little meaning ecologically for aquatic organisms living inshore or near the surface of Lake Michigan. These temperatures are within the daily range of variation at inshore points and the variation in temperature from place to place on a given day often exceed the above figures. Such changes will not cause damage to the ecology of Lake Michigan.

This concludes my prepared paper. Like some of my colleagues I would like to say something about the so-called "white paper" which was prepared and which has been distributed at this meeting by the U. S. Fish and Wildlife Service of the Department of the Interior.

The conclusions involving fishes and other aquatic life appear to have been produced on request after a conclusion had been reached 4 months previously with regard to a 1 degree F. rise. The conclusions were drawn by unnamed persons who made unwarranted assumptions regarding the heat load and behavior of the heat, and who appear to have had very little knowledge of the behavior of fishes and about heated plumes.

I predict that fishes and other aquatic life and the like will not be adversely affected by the judicious placement of a large number of nuclear plants on Lake Michigan.

MR. STEIN: Does that conclude your statement, sir?

DR. RANEY: Yes, sir, Mr. Stein.

MR. STEIN: Are there any comments or questions?

Yes, Mr. Dumelle.

MR. DUMELLE: Dr. Raney, the Federal report on page 75 has this sentence and I just want to make sure that I understand your position. It says, "Available information on the effect of thermal shock on larval fishes ... indicates that the expected temperature rise alone experienced by these fishes while passing through the cooling system would be very injurious or immediately lethal."

Do I understand you correctly that you disagree with this statement?

DR. RANEY: Had I been writing 4 years ago I might have written the same statement. But what I have done is to look into the literature and find out what happens, and we have also run experiments at beach bottom facilities starting in 1966, and our experience is that fast passage with a 20 degree Delta T killed very, very few organisms of any kind.

Now, the literature that I have already quoted -- the report by Kerr which appeared in the report of the California Fish and Game Department used two fishes which we usually think of as sensitive fishes: king or chinook salmon and striped bass. They had a Delta T of 25 degrees; passage was fast. No significant mortalities appeared.

Ninety-five percent of the striped bass were alive after 10 days and most aquarias cannot do that good even without subjecting them to any heat sense.

The chinook salmon passed through 25 degrees Delta T, 5-minute passage, without mortality after 5 days, so that I think that the person that wrote this on page 95 had a gut experience that would be very, very harmful. Experiments to date indicate that it is not, if you have fast passage and a relatively high Delta T, 20 degrees.

MR. DUMELLE: Those experiments, however, do not include all types of species, do they?

DR. RANEY: That is right, sir. At the present time, my group is studying the behavior in this regard of 84 species which live in the Delaware estuary. Other groups, Wes Pipes' colleagues, Lawrence Beer and others -- are also studying the problem, and we are actually accumulating information at a terrific rate. I suppose in this next couple of years we will probably learn more about temperature effects on fishes and other aquatic organisms than we have learned in the last 40 years. The reason for this -- and this is partly in answer to a query of Mr. Stein's -- is that for the first time ecological and experimental studies having to do with heat are tied to an economic base where you can actually do the work in the way that it should have been done many, many years ago. For example, after we have studied a place for a year or two, we begin to know what the additional problems are that need to be studied; but we are going to know a great deal more than my colleagues who originally started studying the fishes of Lake Michigan, for example, when they had one boat and two or three men and they were stuck in this situation maybe for 10 years. Fortunately we now have the economic basis which will justify the kind of ecological studies which should have been done long, long ago.

MR. DUMELLE: Dr. Raney, are you familiar with the Calvert Cliffs plant and permit in Maryland?

DR. RANEY: Yes, sir.

MR. DUMELLE: One of the restrictions on that permit, as I understand it, is an intake velocity into the condenser system of a half a foot per second with a baffling arrangement, so that the fish can swim away from the intake and not be drawn into it. If that is the case, and if, as you say, that no harm will come to these fish, are there any organisms in Chesapeake Bay which are more sensitive to this kind of a temperature rise, which I think is 10 degrees, incidentally?

DR. RANEY: Sir, I have to describe the situation at Calvert Cliffs, which is a 500-foot-long curtain wall, which extends down into the water at a depth of 26 feet. Now, this curtain wall was designed so that the water would be taken from the deepest part of the adjacent bay so as to get 1 or 2 degrees of cooler water. Now, in my opinion, what happened there was that we got 1 or 2 degrees as heat, and we get less plankton because most of the time the plankton is not concentrated near the bottom but it is closer to the surface, although there might be daily migrations to and from the surface.

So that we took these two points -- and I say we, I was not involved in the planning at that stage -- but we got a few degrees, we were going to save the plankton, but what we did was to create a hell of a fish trap and I am certain that we are going to have troubles. But we have proceeded to undertake studies under my direction on the Pacific Coast so that when this plant goes into operation that we will be effectively able to lift these fishes out from in front of the 24 or 28 screens -- I have forgotten how many there are now but there are a great number of them -- and to pass them through a sluiceway and back out to the lake.

So you see, I hope you don't think that I am disagreeing with you on the facts, because actually I was there and I know what they are. We sacrificed fishes to gain cold water and save plankton.

MR. DUMELLE: Thank you.

MR. STEIN: Are there any more questions?

You know with that recital -- and I guess we are all familiar at least in Washington with Calvert Cliffs -- if we have troubles and then we are working out that with a study, our purpose here is to avoid those troubles, isn't it?

DR. RANEY: Was that a question, sir?

MR. STEIN: Yes.

DR. RANEY: That is exactly right. That is our purpose here. And from what we know and what we have presented and will present, and particularly from the actual field studies done by Dr. John Ayers, a former colleague of Cornell, I can certify that we can avoid the problems by having a reasonable mixing zone and that a great deal of the water of Lake Michigan can be used for cooling and that, in my opinion, will be -- in terms of the human ecology, this would be the highest and best use of that water particularly when we can do it without interfering with other recreational values including the sport fishery.

MR. STEIN: Do you have any more, Mr. Dumelle?

MR. DUMELLE: I just want to make sure I understand Dr. Raney.

At Calvert Cliffs, then, you sacrificed the fish to save the plankton. Does this mean, then, that you would have injured the plankton in some way had you not done this? And, if so, at what temperatures or at what intake velocity would this abrasion or this cooking have occurred?

DR. RANEY: Well, if you create a screening system at the end of a long canal, as the fishes approach the screen they sense the screen using their lateral line system which picks up low frequency vibrations. They immediately turn and face toward the current and they start swimming and they swim and swim and swim for days or months, but don't get anywhere. They just stay in the same position. I have observed this at the Santa Onofre nuclear plant in California and I am sure that this is what happens, and ultimately they fall back against the screens. These screens are vertical trouting screens. They come up and are washed off by a jet and they fall into a bin and they are taken out to a local dump or they are ground up and passed back into the ecosystem. The latter system is probably preferable.

Now, the point here is that we ought to prevent the fishes from getting into these places in the first place rather than to design a pumping system later to try to get them out, which they tried to do at Santa Onofre.

Now, I dislike to criticize a colleague, but the recommendation was made early at the Calvert Cliffs with regard to a system -- she had good reason for making it.

She wanted cooler water; she wanted to save the plankton. Her field happens to be diatoms. (Laughter) Personally, I am a student of fishes, striped bass, white perch, the other 80 species in the area, because these things are at the top of the food chain which people are most interested in, in the protection of these organisms.

MR. STEIN: Do I understand you right that we are going to protect the organism in the biota that the professor happens to specialize in? (Laughter)

DR. RANEY: Well, you see, it just happens that my specialty coincides with the most important things.

MR. STEIN: It always does. I have never seen it to fail, but you take the plankton specialist or the diatom specialist and that is the most important thing to them. That is a little subjective test, I think.

MR. DUMELLE: Can the fish swim against the half-a-second-per-minute current?

DR. RANEY: Can what?

MR. DUMELLE: Can the fish swim against the half-foot-per-second current and can they escape from it?

DR. RANEY: We have been working for the last 2 years on the swimming speed of fishes. I have found in the Susquehanna and the Delaware River system that after a fish gets to a size when it does not pass through a screen, virtually all of the species can swim more than a half foot per second. Many of them can swim as much as a foot per second. This is particularly true of the estuarine species. So that if you design a screen with a four-screen current of a half to one foot per second and have a bypass through which the fish can escape, you have, I think, about the most effective design you can get. But the bypass part of it is very important because regardless of the swim speed, the fish cannot swim forever at a half foot or one foot or any other speed.

MR. STEIN: By the way, I think that is the point and maybe I am mistaken on this, but if I am, Dr. Raney, I would like to be corrected. It is like having a fish on the line. It isn't a question of how fast the fish can swim, although that is important, but against a constant pressure they have to give up sooner or later.

DR. RANEY: They do unless you have the type of screen that we are working on now. Incidentally, I will put in a plug for the U. S. Bureau of Commercial Fisheries in this regard. Danny Bates of Portland, Oregon, has for the last 15 years been working on a horizontal traveling screen, and I think that this is our best hope at the moment of all of the screening devices that I have seen in the world. I think this is the one that gives us some hope -- this screen, which is like a fireplace screen which rotates something like a ski tow does. You place it at an angle across a canal, and as the fish come down, they turn, face away from the screen, and they are guided downstream to a bypass where you direct them and put into this a trap and that takes them 70 or 80 miles away, or bypasses them back into a near body of water.

This is very, very important, but the technology for this is not immediately available. This is something that, if it had been available, we could have used, for example, at the Zion plant. It is not that close, but within the next 4 years I think you will see Rex Chainbelt or Carswell or some of these other companies introducing this.

MR. STEIN: Sir, isn't that just the point? The time for ecology or the time we have to work on -- and I know the time you have for development -- may be different in the framework, but if we are dealing with these plants and then we have a device that has been in development for 15 years and we need 4 years to go -- and I fully accept your estimate -- that is 19 years. And if we have made a mistake with the plants in authorizing one of these plants and then we have to wait for a 19-year study and development to straighten something out, we may be in some difficulty. I think the facts and testimony you are giving are very pertinent, but I think you are pointing up some of the problems that, I think, the panel faces.

DR. RANEY: Mr. Stein, could I comment on that, please?

MR. STEIN: Yes.

DR. RANEY: This is exactly right. In the last 2 years, I think we have learned more than we have the last 40 years with a great many aspects of fish behavior and fish physiology and how to do and doing ecological studies.

For many years, within the United States Bureau of Fisheries and other governmental agencies, certainly at the universities -- and I can speak better to this point -- many people have worked with budgets that would not enable them to do much more than to crawl. Those days are over, thank heavens. In other words, the press, the environmental press is such now that funds are available so that we can do these things that many of us have realized needed to be done but that money was never available.

MR. STEIN: Thank you.

I know you said you were speaking for yourself, and not necessarily the industry. But I hope you possibly were speaking for all of us when you said on Page 16, "We have the knowledge to design powerplants so as to mitigate possible environmental effects."

Well, if we could all agree on that I think we have made a tremendous advance. If you agree with that, maybe we can put that forward as a basis for moving forward with this conference.

DR. RANEY: I do indeed agree with that and am sure that, as a company and the conferees such as yourselves come closer, exchange ideas more freely, I am certain that we can get a situation where Lake Michigan will be properly used and not ever abused.

MR. STEIN: Now, I just have one last point as a point of clarification. It is on page 3. You say plants will be used in the future and they say after the present near hysteria regarding thermal discharge has subsided -- who do you mean has started it? The State and Federal officials, the public, or the power officials, or the power companies? Who is hysterical?

DR. RANEY: Well, I live in a little different part of the world than you do, sir. I am certain you never have riots or anything of that sort in Washington, but high above Cayuga's waters we occasionally have what I think is environmental hysteria and unfortunately some of my very close colleagues are leaders of this.

If you have looked into the literature which I am quite sure that you have not had time to do, you would see or read dozens and dozens of papers which treat the problem of heat as a pollutant. Now, I am sure that your agency is not responsible for this.

MR. STEIN: Dr. Raney, you know of a little secret because I don't have time to look into the literature. I don't cut off the experts at meetings like this and I can get a full evaluation.

DR. RANEY: Thank you, sir.

MR. STEIN: But if you look at this meeting, sir, I wonder where that hysteria is? I don't see how many people we have gotten here from the public. I bet if you went through this meeting you would find a vast majority of the audience are representatives of the power industry.

I don't see any evidence of not only hysteria, I am not sure how much public interest we have here.

DR. RANEY: Mr. Stein, unfortunately you didn't have a chance to join us last Friday when the Illinois Pollution Control Board met. The meeting was very ably chaired by Mr. Currie, but we did have what I think is an example of hysteria when a person gets up from the audience and, while not listening to any evidence, points at a speaker or a member of the panel and says, "I would like to see you fry." What he meant was, "I would like to see you in hell." And this is a Catholic priest that was doing this.

Now, I am a poor country boy, so I don't understand these things, but I would say that this is hysteria.

MR. STEIN: I am not up on theology. (Laughter)

Are there any other comments or questions?

Thank you very much, Dr. Raney.

How much more have --

MR. FETTEROLF: Just a minute.

Tens of thousands of people fish for yellow perch around the shoreline of Lake Michigan. It is a very valuable species as far as the public is concerned.

The "white paper" expresses concern that the incubation period of yellow perch eggs may be shortened naturally in 1 year and 3 in Lake Michigan, by natural lake temperatures reaching 64 degrees Fahrenheit during incubation; and they further express concern that this will result in mortality of many eggs.

Would you comment on this?

DR. RANEY: I would be most happy to.

The yellow perch has a range which extends at least to South Carolina. I know that it occurs in Lake Waccamaw which is on the border of North-South Carolina, and here you have this kind of situation where these yellow perch down in that part of the world get along perfectly well. They do in Virginia, and they do throughout the Chesapeake Bay area. They are better some places than others, and they do in southern New York and they do in northern New York, and I am sure that although I feel rather sympathetic for the person who wrote that, they are going to continue to get along very well in Lake Michigan.

Now, with the yellow perch and the walleye, you have this peculiar situation that you have what are called dominant year classes, and I can't say that we understand all of the factors that makes for a dominant year class, but what this means, as of this year, for example, you might have a great deal of spawn and all of the eggs survive, but when they hatch out all of the oyster pods and copepods are just right, and so that they grow and a great many more of them survive than did the year before or perhaps the year after.

Now this year class may dominate the fishery for a half dozen years after they get big enough to come into the fishery. Walleyes do this also, and all walleye fishermen are cognizant of that.

Well, although the evidence is based on a little bit of science, the author, I think, was trying to, as

Dr. Pritchard, so ably express it. I think he was trying to state the facts but without looking at the overall reality of what happens in the yellow perch world.

MR. STEIN: Thank you.

MR. FETTEROLF: I have one more question. As a biologist, I am very concerned over one point which was brought out in the "white paper," and that is that cold water species such as the whitefish are making a come-back in Lake Michigan at this time. We are not certain of all of the areas where these fish spawn.

The "white paper," and -- from my personal contact with biologists at Ann Arbor -- has brought out the point that when coregonid eggs hatch, the larvae apparently must go to the surface of the lake to take in some air to fill their swim bladders.

Now, you have stated in your paper that a temperature of 1 to 5 degrees Fahrenheit warmer at the lake surface will not produce a shock on these coregonid larvae in their very delicate condition, as they rise from the bottom or as they would go through a plume, say, it would have even a greater temperature effect.

Now, I would like you to comment on that and defend your position if you would, please.

DR. RANEY: Carlos, thanks for giving me an opportunity to do that.

I have read this statement sometime ago that all fishes that have a duct between the air bladder and the gut -- a rather indelicate thing to be talking about here -- with these small fishes, supposedly they have to come to the surface and take a little gulp of air, and they fill their air bladder and if they don't do this they don't survive.

I am not at all certain that this is true, but we will assume that it is true.

There are another group of fishes that do not have this duct. The duct has disappeared. These are the so-called spiny-rayed fishes. So they just fill their air bladder by using the gases from their vascular system.

Now, if this is true, this larval whitefish happened to have been spawned unfortunately near a plume, and if he rose or was carried into the most heated part of the plume, he would undoubtedly not survive. Now, the passage through a temperature such as 5 degrees or down to 1 degree -- I doubt whether this would be significant.

Now, what we have to do -- Mr. Fetterolf, who asked the question is a very able biologist and I am sure he knows this -- what we have to do is to evaluate this in overall terms with regard to the population dynamics of the whitefish. How much mortality can we take from these accidental happenings, such as the placement of a few dozen or 20 or 30 plumes around the lake? What are the probabilities that a given young whitefish will happen to be unfortunate enough to choose this place to rise to get his first gulp of air and try to relate this to the overall population?

As I look at it -- you see, out of 100,000 of these young whitefish only a couple are going to survive anyway, so that we will consider this as part of the natural mortality. In other words, the plume is a predator in this regard. He would act just like another fish would act if it happened to be nearby and ate this poor young whitefish and this, of course, happens.

MR. STEIN: Did I understand you, again? You are ready to have a hot water plume equated to a fish predator and let that kill fish and just write it off?

DR. RANEY: Well, no, it is a matter of evaluating what you have. Are you going to take a few acres of hot water near the outlet pipe and say we can't have this because occasionally we might kill some fish? Or are you going to take this and permit once-through cooling, saving all of these many millions of dollars that are going to be squandered on cooling towers and use these millions of dollars in public funds for worthwhile projects: cleaning up pollution, domestic, chemical; and cleaning up ghettoes?

MR. STEIN: Dr. Raney, I understand your position perfectly, and I really admire your candor.

I think we have a very good presentation here. Are there any other questions?

If not, thank you very much, sir.

MR. BANE: Mr. Chairman, it is clear that we won't be able to finish our presentation today within the 5:30 limitation or anything like it.

As I said this morning, several of our witnesses are on time schedules which would make it most inconvenient for them to be here tomorrow -- witnesses who have testified today -- and I, therefore, would like to propose, if it is agreeable with you, that our witnesses who have been presented today be opened up at this time for any questions from the public, and that thereafter they be released.

MR. STEIN: Right. I think that might be appropriate.

Without objection from the conferees, are there any members of the public who have any questions to ask at this point?

Mr. Dumelle, go ahead.

By the way, I don't want to foreclose -- I did this for the public. But may I make the suggestion, Mr. Bane, if it is agreeable to the official people, if any people from the State or the Federal Government have questions, you will have people here tomorrow who you feel can reasonably answer those questions? Is that agreeable?

MR. BANE: Yes. Yes, we simply won't be able to have everybody that we presented today. Those that we can hold over, we will. We will have Dr. Pipes, who has been the director of these studies and who has a good overall view of it.

MR. STEIN: Then, let's just take Mr. Dumelle's questions now and terminate it.

MR. BANE: All right.

MR. DUMELLE: Dr. Pritchard.

MR. BANE: Dr. Pritchard, please.

MR. STEIN: Do you want to ask a question?

MR. DUMELLE: I want to ask Dr. Pritchard a question. I don't know if he is here.

MR. STEIN: By the way, which people are going -- sir, Mr. Mayo would like to know which people are going to leave and which people are going to be here tomorrow in case they do have questions. I wonder if you could let him know that.

Is Dr. Pritchard here? I guess not.

MR. BANE: He has gone. He has left town. So, Mr. Dumelle, all I can suggest is: Can we have your questions in writing, and we will see that you get answers and that the answers are distributed also to the chairman.

MR. STEIN: If he isn't here, we will try to ask those questions tomorrow and maybe Mr. Dumelle and Mr. Mayo can frame them. The reason we went along with this is we thought everyone would wait around and be here to answer these questions. We deal with independent contractors too, and I recognize your position. But I think rather than pursue this, this very well may be a cul-de-sac you can get into.

You will know which people are here tomorrow. Let the poeple here reframe their questions accordingly and we will try to get the best information we can when we resume.

Now, we will go back up to the Bal Tabarin Room tomorrow, and I think in view of the fact that we are running slightly behind, we will again reconvene at 9:00 o'clock and we will stand recessed until then.

(The conference adjourned at 5:25 p.m.)

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